CATERPILLAR®

FORM NO. SEBR0541-03

Service Manual

3208
Diesel Truck Engine

2Z1-UP

3208 DIESEL TRUCK ENGINE

2Z1-UP

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STANDARD TORQUE FOR METRIC FASTENERS

NOTE: Take care to avoid mixing metric and inch dimensioned fasteners. Mismatched or incorrect fasteners can result in vehicle damage or malfunction, or possible injury. Exceptions to these torques are given in the Service Manual where needed.

NOTE: Prior to installation of any hardware, be sure components are in near new condition. Bolt and nut threads must not be worn or damaged. Hardware must be free of rust and corrosion. Clean hardware with a non-corrosive cleaner and apply engine oil to threads and bearing face. If thread lock or other compounds are to be applied, do not apply engine oil.

METRIC NUTS AND BOLTS

THREAD SIZE (mm)	STANDARD TORQUE	
	(N•m)	(lb ft)
M6	12 ± 3	9 ± 2
M8	28 ± 7	20 ± 5
M10	55 ± 10	40 ± 7
M12	100 ± 20	75 ± 15
M14	160 ± 30	120 ± 22
M16	240 ± 40	175 ± 30
M20	460 ± 60	340 ± 44
M24	800 ± 100	600 ± 75
M30	1600 ± 200	1200 ± 150
M36	2700 ± 300	2000 ± 225

METRIC TAPERLOCK STUDS

THREAD SIZE (mm)	STANDARD TORQUE	
	(N•m)	(lb ft)
M6	8 ± 3	6 ± 2
M8	17 ± 5	13 ± 4
M10	35 ± 5	26 ± 4
M12	65 ± 10	48 ± 7
M16	110 ± 20	80 ± 15
M20	170 ± 30	125 ± 22
M24	400 ± 60	300 ± 45
M30	650 ± 80	480 ± 60
M36	870 ± 100	640 ± 75

STANDARD TORQUE FOR INCH FASTENERS

Exceptions to these torques are given in the Service Manual where needed.

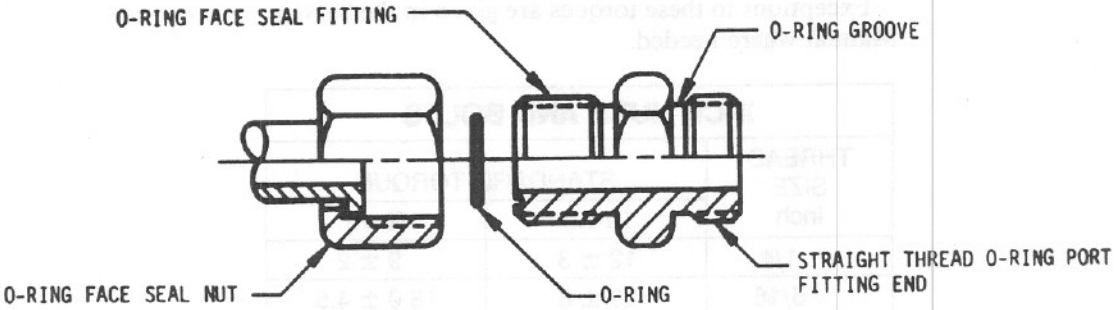
INCH NUTS AND BOLTS

THREAD SIZE inch	STANDARD TORQUE	
	(N•m)	(lb ft)
1/4	12 ± 3	9 ± 2
5/16	25 ± 6	18.0 ± 4.5
3/8	47 ± 9	35 ± 7
7/16	70 ± 15	50 ± 11
1/2	105 ± 20	75 ± 15
9/16	160 ± 30	120 ± 20
5/8	215 ± 40	160 ± 30
3/4	370 ± 50	275 ± 35
7/8	620 ± 80	460 ± 60
1	900 ± 100	660 ± 75
1-1/8	1300 ± 150	950 ± 100
1-1/4	1800 ± 200	1325 ± 150
1-3/8	2400 ± 300	1800 ± 225
1-1/2	3100 ± 350	2300 ± 250

INCH TAPERLOCK STUDS

THREAD SIZE inch	STANDARD TORQUE	
	(N•m)	(lb ft)
1/4	8 ± 3	6 ± 2
5/16	17 ± 5	13 ± 4
3/8	35 ± 5	26 ± 4
7/16	45 ± 10	33 ± 7
1/2	65 ± 10	48 ± 7
5/8	110 ± 20	80 ± 15
3/4	170 ± 30	125 ± 22
7/8	260 ± 40	190 ± 30
1	400 ± 60	300 ± 45
1-1/8	500 ± 70	370 ± 50
1-1/4	650 ± 80	480 ± 60
1-3/8	750 ± 90	550 ± 65
1-1/2	870 ± 100	640 ± 75

O-RING FACE SEAL FITTINGS


O-RING FACE SEAL FITTING
O-RING GROOVE
STRAIGHT THREAD O-RING PORT FITTING END
O-RING FACE SEAL NUT
O-RING

STRAIGHT THREAD O-RING FITTING (FOR O-RING FACE SEAL FITTING ONLY)		
THREAD SIZE inch	STANDARD TORQUE	
	(N•m)	(lb ft)
5/16 - 24	5.0 ± 1.5	45 ± 15 lb in
3/8 - 24	12 ± 2	110 ± 20 lb in
7/16 - 20	20 ± 4	15 ± 3
1/2 - 20	30 ± 5	22 ± 4
9/16 - 18	40 ± 5	30 ± 4
3/4 - 16	100 ± 15	75 ± 10
7/8 - 14	135 ± 15	100 ± 10
1 1/16 - 12	200 ± 25	150 ± 20
1 3/16 - 12	250 ± 25	185 ± 20
1 5/16 - 12	300 ± 40	225 ± 30
1 5/8 - 12	300 ± 40	225 ± 30
1 7/8 - 12	300 ± 40	225 ± 30
2 1/2 - 12	300 ± 40	225 ± 30

O-RING FACE SEAL FITTING NUT		
THREAD SIZE inch	STANDARD TORQUE	
	(N•m)	(lb ft)
9/16 - 18	16 ± 3	12 ± 2
11/16 - 16	30 ± 4	22 ± 3
13/16 - 16	50 ± 7	37 ± 5
1 - 14	90 ± 10	65 ± 7
1 3/16 - 12	120 ± 15	90 ± 10
1 7/16 - 12	160 ± 20	120 ± 15
1 11/16 - 12	190 ± 20	140 ± 15
2 - 12	215 ± 25	160 ± 20

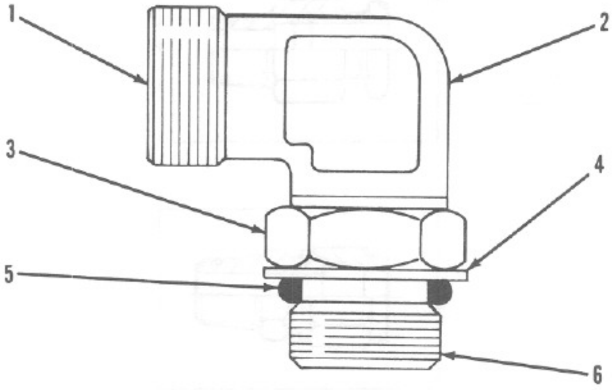
FITTING INSTALLATION

HYDRAULIC LINE INSTALLATION

1. For a metal tube to hose installation, install the tube and tighten all bolts finger tight.
2. Tighten the bolts at the rigid end.
3. Install the hose and tighten all bolts finger tight.
4. Put the hose in a position so that it does not make contact with the machine or another hose.
5. Tighten the bolts on both connections.
6. Start the engine.
7. Move the implement control levers to all positions.
8. Look at the hose during movement of the implement. Make sure hose is not in contact with the machine or other hoses.
9. Shut off the engine.
10. If necessary, put the hose in a new position where it will not make contact when the implement is moved.

ASSEMBLY OF FITTINGS WITH STRAIGHT THREADS AND O-RING SEALS

This type of fitting is used in many applications. The tube end of the fitting will be different in design so that it can be used in many different applications. However, the installation procedure of the fitting is the same. If the tube end of the fitting body is the same as in the illustration (either an elbow or a straight body) it will be necessary to assemble the sleeve on the tube before connecting the tube to the end.



ELBOW BODY ASSEMBLY

1. End of fitting body (connects to tube). 2. Fitting body. 3. Locknut. 4. Backup washer. 5. O-ring seal. 6. End of fitting that goes into other part.

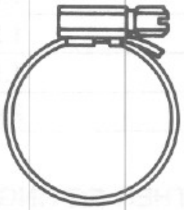
1. Put locknut (3), backup washer (4) and O-ring seal (5) as far back on fitting body (2) as possible. Hold these components in this position. Turn the fitting into the part it is used on until backup washer (4) just makes contact with the face of the part it is used on.
2. To put the fitting assembly in its correct position, turn the fitting body (2) out (counterclockwise) a maximum of 359°. Tighten locknut (3) to the torque shown in the correct chart for the fitting used.

NOTE: If the fitting is a connector (straight fitting), the hex on the body takes the place of the locknut. To install this type fitting, tighten the hex against the face of the part it goes into.

TORQUES FOR FLARED AND O-RING FITTINGS

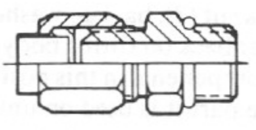
The torques shown in the charts that follow are to be used on the nut part of 37° Flared, 45° Flared and Inverted Flared fittings (when used with steel tubing), O-ring plugs, O-ring fittings and swivel nuts when used in applications to 3000 psi (20 700 kPa).

HOSE CLAMP – BAND TYPE

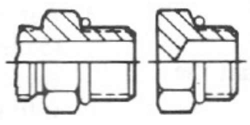


CLAMP WIDTH	TORQUE ON NEW HOSE	RETIGHTENING TORQUE
7.9 mm (.312 in)	0.9 ± 0.2 N•m 8 ± 2 lb in	0.7 ± 0.2 N•m 6 ± 2 lb in
13.5 mm (.531 in)	4.5 ± 0.5 N•m 40 ± 5 lb in	3.0 ± 0.5 N•m 25 ± 5 lb in
15.9 mm (.625 in)	7.5 ± 0.5 N•m 65 ± 5 lb in	4.5 ± 0.5 N•m 40 ± 5 lb in

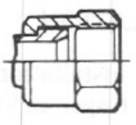
37° FLARED AND STRAIGHT THREAD O-RING FITTINGS



37° FLARED



O-RING
FITTING – PLUG



SWIVEL NUTS

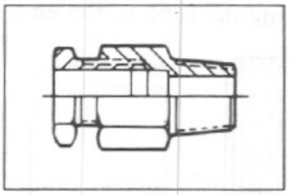
37° FLARED AND STRAIGHT THREAD O-RING FITTINGS (EXCEPT O-RING FACE SEAL FITTINGS)

NOMINAL TUBE O.D.		THREAD SIZE	STANDARD TORQUE	
METRIC	INCH	inch	(N•m)	(lb ft)
3.18	.125	5/16	5.0 ± 1.5	4 ± 1
4.76	.188	3/8	11.0 ± 1.5	8 ± 1
6.35	.250	7/16	16 ± 2	12 ± 1
7.94	.312	1/2	20 ± 5	15 ± 4
9.52	.375	9/16	25 ± 5	18 ± 4
9.52	.375	5/8	35 ± 5	26 ± 4
12.70	.500	3/4	50 ± 7	37 ± 5
15.88	.625	7/8	65 ± 7	48 ± 5
19.05	.750	1-1/16	100 ± 10	75 ± 7
22.22	.875	1-3/16	120 ± 10	90 ± 7
25.40	1.000	1-5/16	135 ± 15	100 ± 11
31.75	1.250	1-5/8	180 ± 15	135 ± 11
38.10	1.500	1-7/8	225 ± 15	165 ± 11
50.80	2.000	2-1/2	320 ± 30	240 ± 22

TIGHTENING OTHER FITTINGS

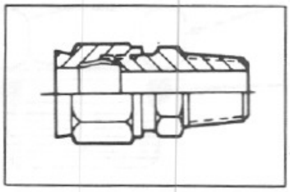
Hi Duty (Shear Sleeve) Tube Fittings

After tube has been put through the nut and makes contact against the tube shoulder in the fitting body, turn the nut with a wrench until a small decrease in torque is felt. This is an indication that the sleeve has been broken off the nut. Hold the tube to prevent turning and tighten the nut 1-1/2 turns.

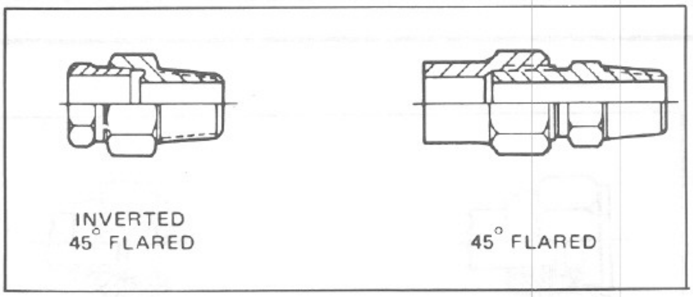


Hi Seal Fittings

Put nut and sleeve over the tubing with the short heavy end of the sleeve facing the end of tubing. Put the tube end against the counterbore in the body of the fitting and tighten until nut is over the last thread on the body. The remainder of space is used whenever the fitting is removed and installed again.



45° FLARED AND 45° INVERTED FLARE FITTINGS

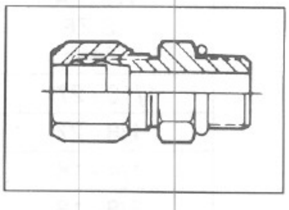


45° FLARED AND 45° INVERTED FLARE FITTINGS				
NOMINAL TUBE O.D.		THREAD SIZE inch	STANDARD TORQUE	
METRIC	INCH		(N•m)	(lb ft)
3.18	.125	5/16	5.0 ± 1.5	4 ± 1
4.76	.188	3/8	8.0 ± 1.5	6 ± 1
6.35	.250	7/16	11 ± 2	8 ± 1
7.94	.312	1/2	17 ± 3	13 ± 2
9.52	.375	5/8	30 ± 3	22 ± 2
11.11	.438	11/16	30 ± 3	22 ± 2
12.70	.500	3/4	38 ± 4	28 ± 3
15.88	.625	7/8	50 ± 5	37 ± 4
19.05	.750	1-1/16	90 ± 8	65 ± 6
22.22	.875	1-1/4	100 ± 10	75 ± 7

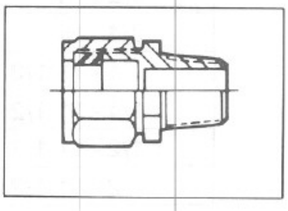
TIGHTENING OTHER FITTINGS

Ermeto Tube Fittings

Put nut and sleeve over the tube with head or shoulder end of sleeve next to nut. Push tube into counterbore of fitting body as far as possible. Turn nut clockwise until sleeve holds tube and prevents movement. Tighten the nut 1-1/4 turns more to seat sleeve and give a locking action. When necessary to assemble again, put sleeve over tube and tighten nut until a sudden increase in torque is felt. Then tighten 1/6 to 1/3 turn more to seat the sleeve.

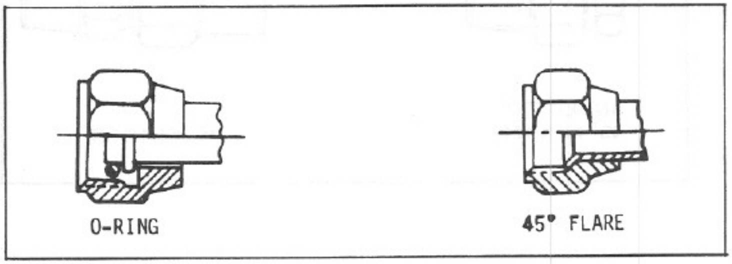


Flex Fittings



Put nut and sleeve over the tubing and push tube into counterbore of fitting body as far as possible. Tighten the nut until it is against the hex part of the fitting body.

AIR CONDITIONING AND TAPERED PIPE THREAD FITTINGS



AIR CONDITIONING FITTINGS

THREAD SIZE inch	O-RING FITTING END		45° FLARE FITTING END			
			STEEL TUBES		ALUMINUM TUBES	
	STANDARD TORQUE		STANDARD TORQUE		STANDARD TORQUE	
	N•m	(lb ft)	N•m	(lb ft)	N•m	(lb ft)
5/8 - 18	18 ± 4	13 ± 3	30 ± 3	22 ± 2	23 ± 3	17 ± 2
3/4 - 16	37 ± 4	27 ± 3	52 ± 5	38 ± 4	33 ± 4	24 ± 3
7/8 - 14	40 ± 4	30 ± 3	60 ± 7	44 ± 5	38 ± 4	28 ± 3
1 1/16 - 14	45 ± 5	33 ± 4	75 ± 8	55 ± 6	50 ± 5	37 ± 4

TAPERED PIPE THREAD FITTINGS

PIPE THREAD SIZE inch	STANDARD TORQUE			
	THREADS WITH 1E2200E SEALANT		THREADS WITHOUT SEALANT	
	N•m	(lb ft)	N•m	(lb ft)
1/16 - 27	15	11	20	15
1/8 - 27	20	15	25	18
1/4 - 18	25	18	35	26
3/8 - 18	35	26	45	33
1/2 - 14	45	33	60	45
3/4 - 14	60	45	75	55
1 - 11 1/2	75	55	90	65

Important Safety Information

Most accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or other persons.

The hazards are identified by the "Safety Alert Symbol" and followed by a "Signal Word" such as "WARNING" as shown below.

⚠ WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning, explaining the hazard, can be either written or pictorially presented.

Operations that may cause product damage are identified by NOTICE labels on the product and in this publication.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedures you choose.

The information, specifications, and illustrations in this publication are on the basis of information available at the time it was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service given to the product. Obtain the complete and most current information before starting any job. Caterpillar dealers have the most current information available. For a list of the most current publication form numbers available, see the Service Manual Contents Microfiche, REG1139F.

⚠ WARNING

SAFETY

⚠ WARNING

Improper performance of lubrication or maintenance procedures is dangerous and could result in injury or death. Read and understand the lubrication and maintenance procedures, recommended by Caterpillar, that are outlined in the OPERATION MAINTENANCE GUIDE and/or OWNER'S MANUAL for this product before performing any lubrication or maintenance.

Do not operate this product unless you have read and understood the instructions. Improper operation is dangerous and could result in injury or death.

The serviceman or mechanic may be unfamiliar with many of the components and systems of this product. This makes it important to use caution when performing service work. A knowledge of the system and/or components is important before the removal or disassembly of any component.

Because of the size of some components, the serviceman or mechanic should check the weights noted in this Manual. Use proper lifting procedures when removing any components.

Following is a list of basic precautions that should always be observed.

1. Read and understand all Warning plates and decals before operating, lubricating or repairing this product.
2. Make sure the work area around the product is made safe and be aware of hazardous conditions that may exist.
3. Always wear protective glasses and protective shoes when working. In particular, wear protective glasses when a hammer or sledge is used for pounding to make repairs. Use welders gloves, hood/goggles, apron and other protective clothing appropriate to the welding job being performed. Do not wear loose-fitting or torn clothing. Remove all rings from fingers when working on machinery.
4. If an engine must be started to make pressure or speed checks, be sure all guards and shields are installed. To help prevent an accident caused by parts in rotation, work carefully around machinery that has been put into operation.
5. If an engine has been running and the coolant is hot, loosen the filler cap slowly and let the pressure out of the cooling system, before any caps, plugs or lines are removed or disconnected.
6. Corrosion inhibitor contains alkali. Avoid contact with eyes. Avoid prolonged or repeated contact with skin. Do not take internally. In case of contact, immediately wash skin with soap and water. For eyes, flush with large amounts of water for at least 15 minutes. CALL PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.
7. Do not smoke when an inspection of the battery electrolyte level is made. Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operating. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Do not let electrolyte solution make contact with skin or eyes. Electrolyte solution is an acid. In case of contact, immediately wash skin with soap and water. For eyes, flush with large amounts of water for at least 15 minutes. CALL PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.
8. Disconnect battery and discharge any capacitors before starting any repair work. Hang "Do Not Operate" tag in the Operator's compartment or on the controls.
9. Do not work on anything that is supported only by lift jacks or a hoist. Always use blocks or proper stands to support the product before performing any service work.
10. Relieve all pressure in air, oil or water systems before any lines, fittings or related items are disconnected or removed. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do not check for pressure leaks with your hand. High pressure oil or fuel can pierce the skin.

⚠ WARNING

11. Never bend a fuel injection line, or install a line which has been bent. Keep the fuel injection lines and connections clean. Be sure to install caps and covers anytime a line is removed or disconnected.

12. During service work, do not hit the fuel injection lines with wrenches or other tools. When lines are installed, use the correct torque to tighten connections and be sure all clamps and dampers are correctly installed.

13. Make sure all fuel injection lines and pressure oil lines have enough clearance to prevent contact with any other component. Do not put any fuel or oil lines close to a hot component.

14. To avoid back injury use a hoist or get help when lifting components which weigh 23 kg (50 lb.) or more. Make sure all chains, hooks, slings, etc., are in good condition and are of the correct capacity. Be sure hooks are positioned correctly. Lifting eyes are not to be side loaded during a lifting operation.

15. To avoid burns, be alert for hot parts on products which have just been stopped and hot fluids in lines, tubes and compartments.

16. Be careful when removing cover plates. Gradually back off the last two bolts or nuts located at opposite ends of the cover or device and pry cover loose to relieve any spring or other pressure, before removing the last two bolts or nuts completely.

17. Be careful when removing filler caps, breathers and plugs on the product. Hold a rag over the cap or plug to prevent being sprayed or splashed by liquids under pressure. The danger is even greater if the product has recently been stopped because fluids can be hot.

18. Always use tools that are in good condition and be sure you understand how to use them before performing any service work. Use only Caterpillar replacement parts.

19. Reinstall all fasteners with same part number. Do not use a lesser quality fastener if replacements are necessary.

20. Before doing electrical work, disconnect battery. Do not damage wiring during removal operations. Reinstall the wiring so it is not damaged nor will it be damaged in operation by contacting sharp corners, or by rubbing against some object or hot surface. Do not connect wiring to a line containing fluid.

21. Repairs which require welding should be performed only with the benefit of the appropriate reference information and by personnel adequately trained and knowledgeable in welding procedures. Make reference to "Techniques of Structural Repair Course" form number SEGV2549. Determine type of metal being welded and select correct welding procedure and electrodes, rods or wire to provide a weld metal strength equivalent at least to that of parent metal.

22. Be sure all protective devices including guards and shields are properly installed and functioning correctly before starting a repair. If a guard or shield must be removed to perform the repair work, use extra caution. After the repair is completed, reinstall any guard or shield that was removed.

23. Caution should be used to avoid breathing dust that may be generated when handling components containing asbestos fibers. If this dust is inhaled, it can be hazardous to your health. Components in Caterpillar products that may contain asbestos fibers are brake pads, brake band and lining assemblies, clutch plates and some gaskets. The asbestos used in these components is usually bound in a resin or sealed in some way. Normal handling is not hazardous as long as airborne dust which contains asbestos is not generated.

If dust which may contain asbestos is present, there are several common sense guidelines that should be followed.

a. Never use compressed air for cleaning.

b. Avoid brushing or grinding of asbestos containing materials.

c. For clean up, use wet methods or a vacuum equipped with a high efficiency particulate air (HEPA) filter.

d. Use exhaust ventilation on permanent machining jobs.

e. Wear an approved respirator if there is no other way to control the dust.

f. Comply with applicable rules and regulations for the work place (for example in the U.S.A., OSHA requirements as set forth in 29 CFR 1910.1001).

g. Follow environmental rules and regulations for disposal of asbestos.

h. Avoid areas where asbestos particles may be in the air.

SPECIFICATIONS

3208 DIESEL TRUCK ENGINE

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NOTE: Refer to the complete Service Manual for information not found here.

A "C" in the left margin is an indication of a change from the former issue.

Introduction

The specifications given in this book are on the basis of information available at the time the book was written. These specifications give the torques, operating pressures, measurements of new parts, adjustments and other items that will affect the service of the product.

When the words "use again" are in the description, the specification given can be used to determine if a part can be used again. If the part is equal to or within the specification given, use the part again.

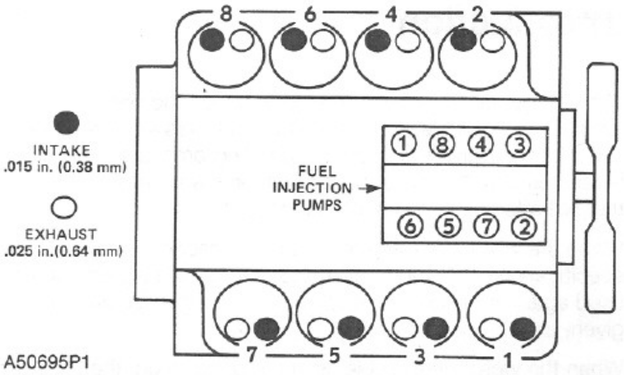
When the word "permissible" is in the description, the specification given is the "maximum or minimum" tolerance permitted before adjustment, repair and/or new parts are needed.

A comparison can be made between the measurements of a worn part and the specification of a new part to find the amount of wear. A part that is worn can be safe to use if an estimate of the remainder of its service life is good. If a short service life is expected, replace the part.

NOTE: The specification given for "use again" and "permissible" are intended for guidance only and Caterpillar Inc. hereby expressly denies and excludes any representation, warranty or implied warranty of the reuse of any component.

Specifications

Engine Design



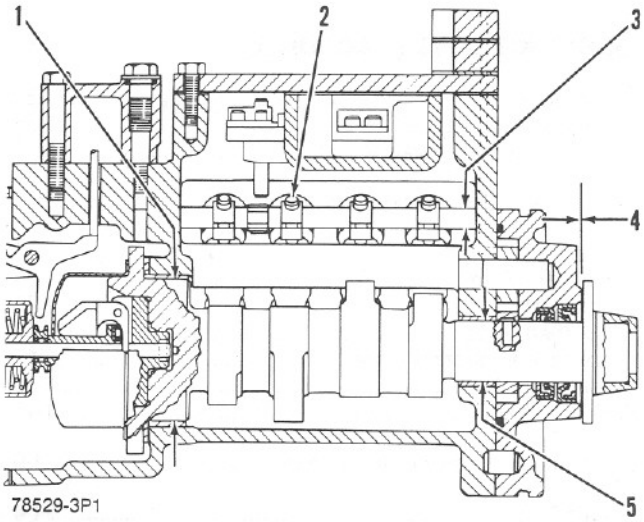
A50695P1

Cylinder, Valve And Injection Pump Location

Bore	114.3 mm (4.5 in)
Stroke	127.0 mm (5.0 in)
Number Of Cylinders	8
Cylinder Arrangement	90°V
Firing Order (Injection Sequence)	1,2,7,3,4,5,6,8
Direction Of Rotation (As Seen From Flywheel End)	Counterclockwise

Fuel Injection Pump

Firing order (injection sequence)	1,2,7,3,4,5,6,8
Injection timing BTC (before top center):	
Engines with 1W6742 Fuel Pump Group	8 ± 1°
Engines with 7C8966 and 7W5479 Fuel Pump Groups	10 ± 1°
Engines with 7E9890 Fuel Pump Groups	11.5 ± 1°
Engines with 7C8968, 7C8969, 7C8970, 7C8971 and 4P4260 Fuel Pump Groups	12.5 ± 1°
All other engines	15 ± 1°
Torque for the nuts that hold the fuel lines (Use 5P0144 Fuel Line Socket)	40 ± 7 N•m (30 ± 5 lb ft)



78529-3P1

(1) Bore in the rear bearing for the camshaft (new) .... 60.325 ± 0.013 mm (2.3750 ± .0005 in)
Diameter of rear bearing surface (journal) of the camshaft (new) .... 60.249 ± 0.013 mm (2.3720 ± .0005 in)
Maximum permissible clearance between the bearing and the camshaft bearing surface (journal) (worn) .... 0.15 mm (.006 in)

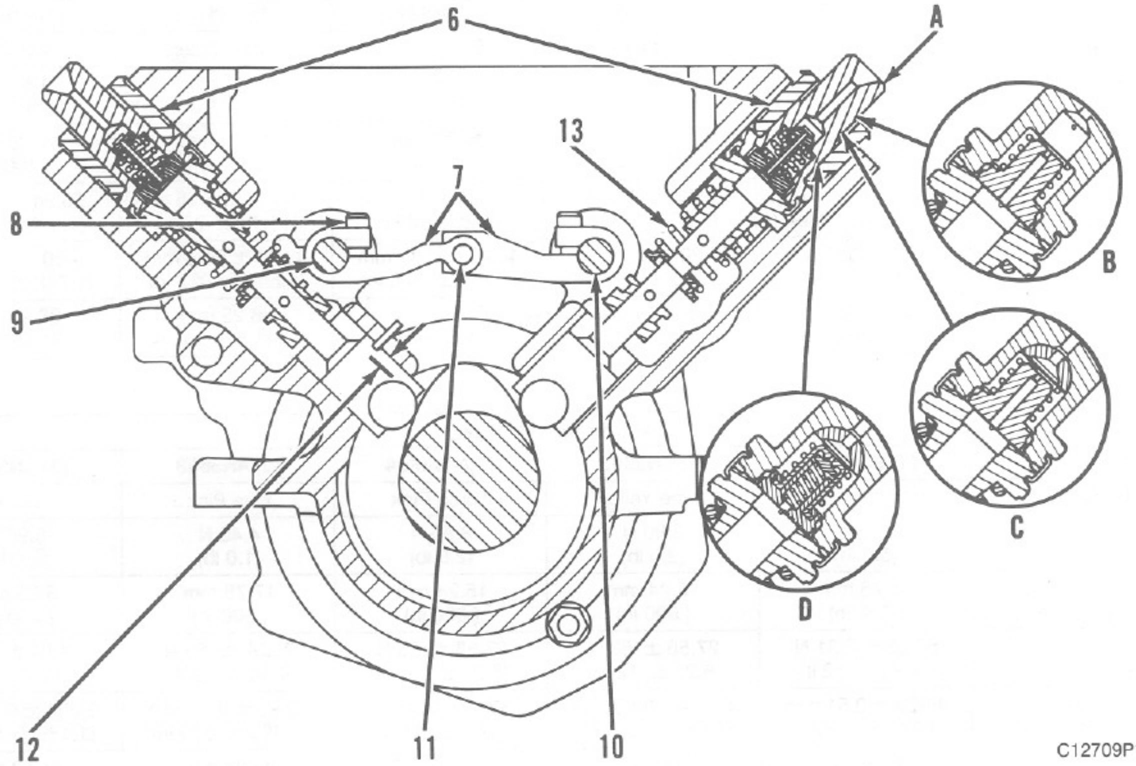
(2) Torque for screws that hold sleeve control levers .... 2.8 ± 0.2 N•m (24 ± 2 lb in)

(3) Bore in the housing for the fuel control shaft (new) .... 8.999 ± 0.013 mm (.3543 ± .0005 in)
Diameter of sleeve control shaft (new) .... 8.966 ± 0.008 mm (.3530 ± .0003 in)
Maximum permissible clearance between the bore in the housing and the sleeve control shaft (worn) ..... 0.08 mm (.003 in)

(4) End play for camshaft with sleeve installed (new) .... 0.58 ± 0.46 mm (.023 ± .018 in)

NOTE: When installing sleeve on end of camshaft, support the camshaft to prevent damage to parts inside of injection pump and governor housing.

(5) Bore in the front bearing for the camshaft (new) .... 25.413 ± 0.013 mm (1.0005 ± .0005 in)
Diameter of front bearing surface (journal) of the camshaft (new) .... 25.375 ± 0.013 mm (.9990 ± .0005 in)
Maximum permissible clearance between the bearing and the camshaft bearing surface (journal) (worn) .... 0.10 mm (.004 in)



(6) Torque for bushing .... 82 ± 7 N•m (60 ± 5 lb ft)

(7) Crossover levers.

NOTE: For adjustment of crossover levers, see the Testing And Adjusting Section.

(8) Torque for screws that hold crossover levers .... 2.8 ± 0.2 N•m (24 ± 2 lb in)

(9 and 10) Fuel control shafts.

(11) Dowel pin (linkage between crossover levers).

(12) Distance guide pin extends into bore ..... 1.20 ± 0.10 mm (.047 ± .004 in)

NOTE: Install guide pin with slot toward the top of the lifter bore.

(13) 9N5862 Spring for injection pump:

Length under test force	35.13 mm (1.383 in)
Test force	56.7 ± 6.6 N (12.4 ± 1.4 lb)
Free length after test	40.80 mm (1.606 in)
Outside diameter	18.49 mm (.728 in)

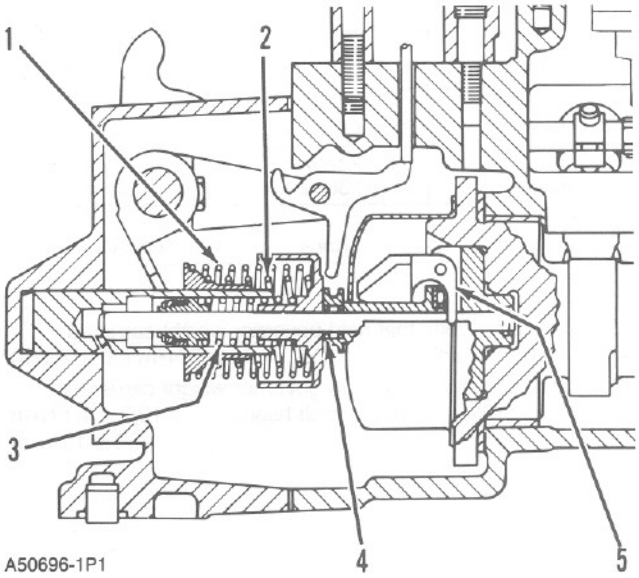
A. Reverse Flow Check Valve (RFC).

B. Orificed Delivery Valve (ODV).

C. Orificed Delivery Valve - Lo Volume (ODV).

D. Orificed Reverse Flow Check Valve (ORFC).

Governor



Governor Spring Chart

Part No.	(1) 1W4925	(1) 6N2129	(1) 4N9226	(1) 4N6119	(1) 4N5661
Color code (Stripes)	One Purple	Two Pink	Two Green	Three Green	Two White
Put a force on spring of	17.79 N (4.0 lb)	8.90 N (2.0 lb)	17.79 N (4.0 lb)	13.34 N (3.0 lb)	13.34 N (3.0 lb)
Then add more force to make spring shorter by	15.00 mm (.590 in)	17.78 mm (.700 in)	17.78 mm (.700 in)	17.78 mm (.700 in)	17.78 mm (.700 in)
Total test force	59.82 ± 1.34 N (13.40 ± .30 lb)	36.92 ± 0.89 N (8.30 ± .20 lb)	67.61 ± 1.51 N (15.20 ± .34 lb)	50.71 ± 1.16 N (11.40 ± .26 lb)	56.94 ± 1.51 N (12.80 ± .34 lb)
Free length after test	38.97 ± 0.51 mm (1.534 ± .020 in)	44.20 ± 0.51 mm (1.740 ± .020 in)	44.20 ± 0.51 mm (1.740 ± .020 in)	42.14 ± 0.53 mm (1.659 ± .021 in)	44.20 ± 0.51 mm (1.740 ± .020 in)
Outside diameter	38.56 mm (1.518 in)	37.84 mm (1.490 in)	38.56 mm (1.518 in)	38.25 mm (1.506 in)	38.25 mm (1.506 in)

Governor Spring Chart

Part No.	(1) 9L6508	(1) 7N3807	(1) 1W6804	(2) 4N5663	(3) 6N2517
Color code (Stripes)	One Yellow	Three Yellow	Three Pink	One Pink	None
Put a force on spring of	22.24 N (5.0 lb)	8.90 N (2.0 lb)	8.90 N (2.0 lb)	4.45 N (1.0 lb)	8.90 N (2.0 lb)
Then add more force to make spring shorter by	17.78 mm (.700 in)	15.24 mm (.600 in)	15.24 mm (.600 in)	17.78 mm (.700 in)	5.08 mm (.200 in)
Total test force	87.63 ± 2.31 N (19.70 ± .52 lb)	27.58 ± .53 N (6.20 ± .12 lb)	27.58 ± .53 N (6.20 ± .12 lb)	20.02 ± .53 N (4.50 ± .12 lb)	24.91 ± .80 N (5.60 ± .18 lb)
Free length after test	44.20 ± 0.51 mm (1.740 ± .020 in)	42.14 ± 0.53 mm (1.659 ± .021 in)	52.4 ± 1.0 mm (2.063 ± .039 in)	42.93 ± 0.51 mm (1.690 ± .020 in)	31.24 ± 0.51 mm (1.136 ± .020 in)
Outside diameter	38.56 mm (1.518 in)	37.84 mm (1.490 in)	37.84 mm (1.490 in)	29.06 mm (1.144 in)	14.83 mm (.584 in)

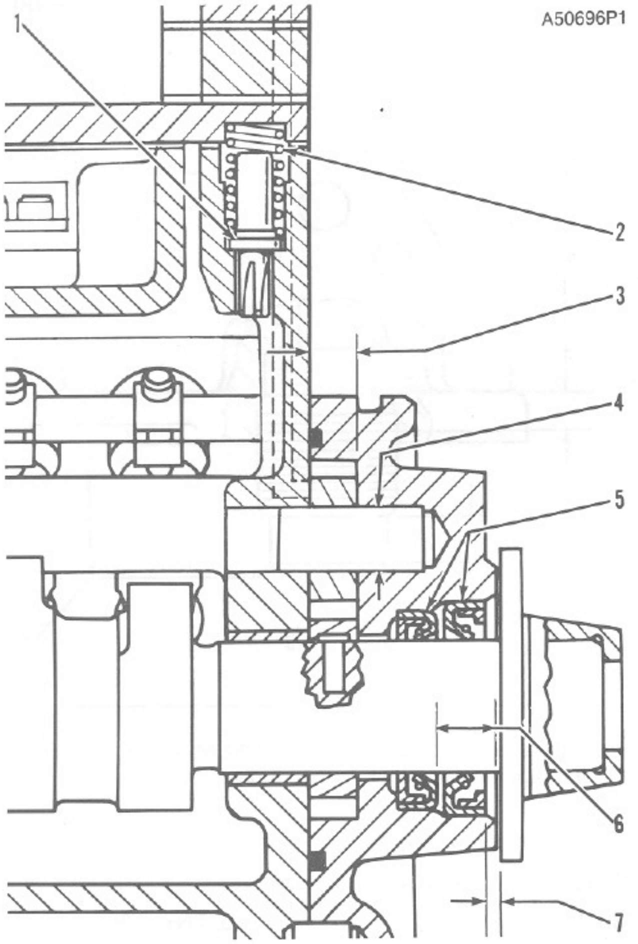
(4) Overfueling Springs

Part No.	4N0527	6N6662
Length under test force	8.71 mm (.343 in)	19.00 mm (.748 in)
Test force	0.85 ± 0.08 N (.19 ± .02 lb)	0.84 ± 0.08 N (.189 ± .02 lb)
Free length after test	18.29 mm (.720 in)	28.60 mm (1.126 in)
Outside diameter	9.14 mm (.360 in)	9.14 mm (.360 in)
Color code (Stripes)	None	One White

(5) Torque for bolts that hold governor weight carrier to camshaft (earlier) .... 14 ± 3 N•m (10 ± 2 lb ft)

Torque for bolts that hold governor weight carrier to camshaft (later with thin bolt head) .... 10.2 ± 1.1 N•m (90 ± 10 lb in)

Fuel Transfer Pump



(1) Bypass valve:
Fuel pressure at FULL LOAD .. 205 ± 35 kPa (30 ± 5 psi)

(2) 4N605 Spring for bypass valve:
Length under test force .... 22.35 mm (.880 in)
Test force .... 15.7 ± 0.80 N (3.53 ± .18 lb)
Free length after test .... 43.92 mm (1.729 in)
Outside diameter .... 13.39 mm (.527 in)

(3) Thickness of gears (new) .... 9.489 ± 0.008 mm (.3736 ± .0003 in)

Depth of counterbore (new) .... 9.525 ± 0.013 mm (.3750 ± .0005 in)

(4) Diameter of shaft for idler gear .... 12.482 ± 0.008 mm (.4914 ± .0003 in)

Bore in idler gear .... 12.512 ± 0.008 mm (.4926 ± .0003 in)

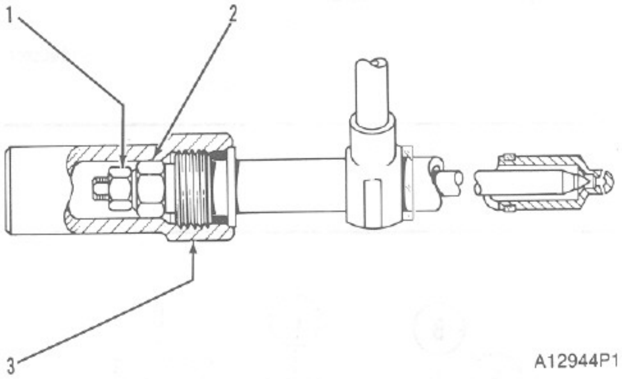
(5) Put a thin layer of 5S1454 Sealing Compound on the outside diameter of the seals before installation. Remove the extra sealing compound after assembly.

(6) Install inner seal from outside edge of body assembly to a distance of .... 11.51 ± 0.25 mm (.453 ± .010 in)

(7) Install outside seal from outside edge of body assembly to a distance of .... 0.76 ± 0.25 mm (.030 ± .010 in)

Injection Nozzles

9N3979 and 1W5829



Bench test nozzles using clean SAE J967 Calibration Oil (Kent-Moore Corp J-26400 or Viscor Calibration Fluid 1487C-SAE J-967C) at a temperature of .... 18 to 20°C (65 to 70°F)

Nozzle setting pressures (valve lift adjustment screw turned 3/4 ± 1/8 turn from closed position):

Used nozzle .... 10 300 to 17 690 kPa (1500 to 2600 psi)
Used, adjusted nozzle .... 16 545 to 17 690 kPa (2400 to 2600 psi)

Return oil leakage test pressure .... 9630 to 11 045 kPa (1400 to 1600 psi)

Leakage in 15 seconds .... NO minimum or maximum

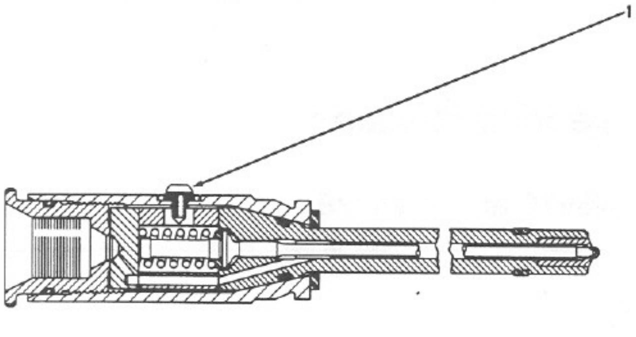
Maximum tip leakage is 20 drops in 15 seconds with a pressure of 1380 kPa (200 psi) less than opening pressure.

(1) Torque for valve lift locknut .... 4.0 to 5.1 N•m (35 to 45 lb in)

(2) Torque for pressure screw locknut .... 8.0 to 9.1 N•m (70 to 80 lb in)

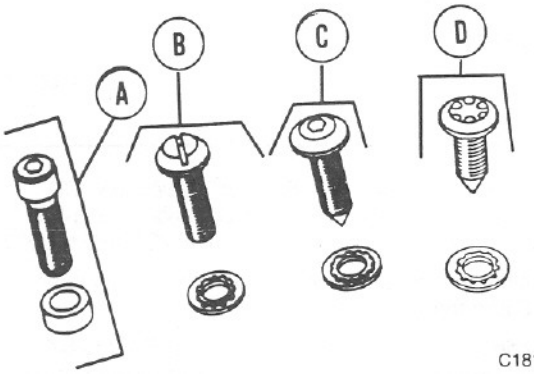
(3) Torque for cap .... 12.4 to 13.6 N•m (110 to 120 lb in)

c 7000 Series Nozzle



B46400P1

(1) Bleed screw.



C18178P1

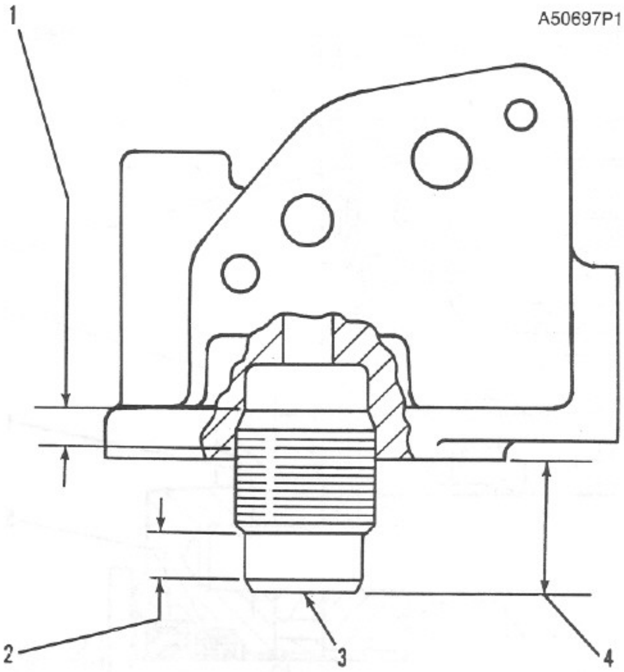
Tighten bleed screws to the following torques:

Bleed screw A .... 0.9 ± 0.1 N•m (8 ± 1 lb ft)
Bleed screw B .... 1.8 ± 0.2 N•m (16 ± 2 lb ft)
Bleed screws C and D .... 2.2 ± 0.8 N•m (20 ± 7 lb ft)

NOTE: All fuel injection line nuts are tightened to a torque of .... 42 ± 7 N•m (31 ± 5 lb ft)

Fuel Filter Base

A50697P1



(1) Put 9S3263 Thread Lock Compound on the threads of the tapered end of the stud to a distance of .... 7.6 mm (.30 in)

(2) Sealing surface of stud.

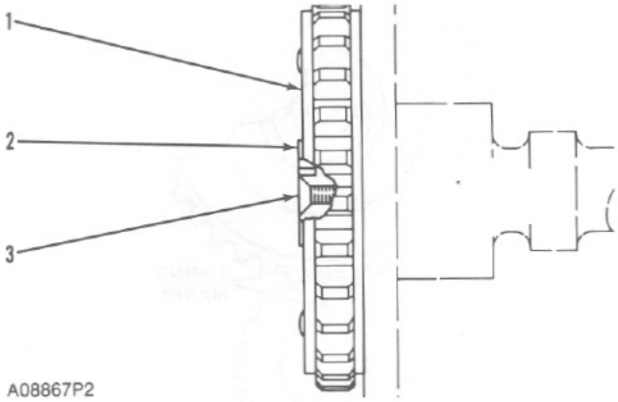
NOTE: Do not damage this surface.

(3) Torque for stud .... 70 ± 7 N•m (50 ± 5 lb ft)

(4) Distance from sealing surface of base to end of stud .... 24.6 ± 1.3 mm (.97 ± .05 in)

Automatic Timing Advance Unit

3.5° and 5° unit



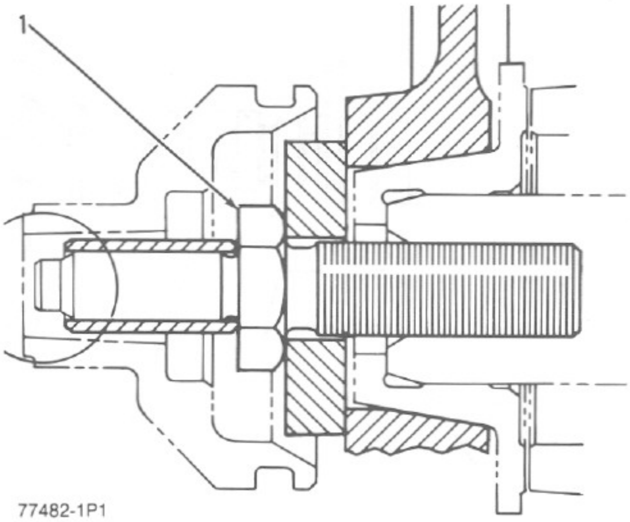
A08867P2

End play between washer (2) and timing advance unit
(1) .... 0.08 to 0.94 mm (.003 to .037 in)

(3) Torque for screw .... 7.9 ± 0.6 N•m (70 ± 5 lb in)

"Stake" (make a mark with a punch) screw (3) in two places.

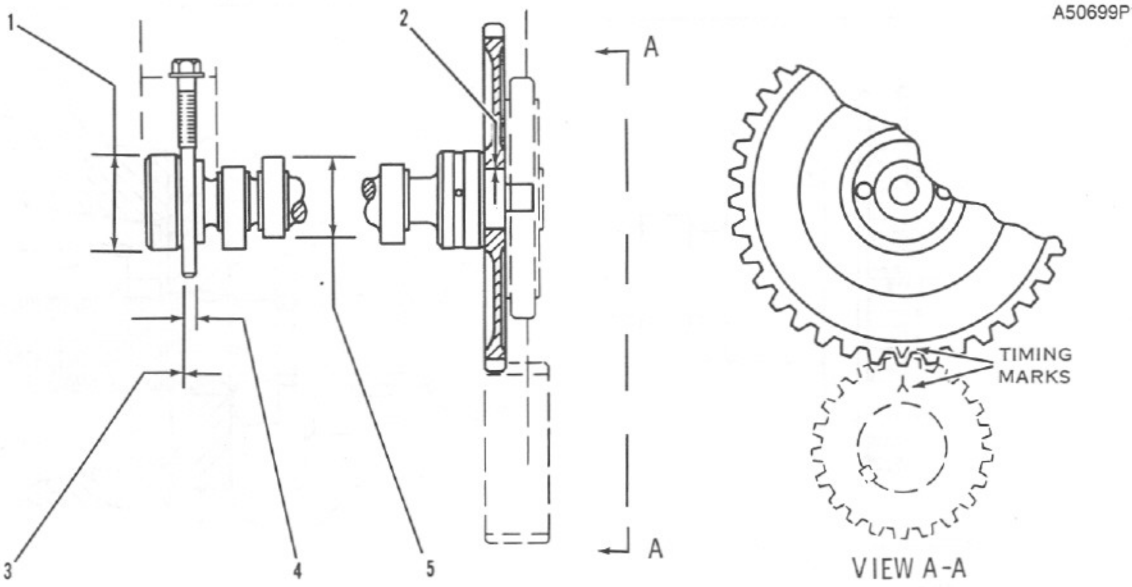
Drive Gear For The Injection Pump



77482-1P1

(1) Torque for the bolt that holds the drive gear to the camshaft of the injection pump .... 149 ± 14 N•m (110 ± 10 lb ft)

c Camshaft



(1) Diameter of the surfaces (journals) for the camshaft bearings (new) .. 63.500 ± 0.013 mm (2.5000 ± .0005 in)
Bore in the five bearings for the camshaft (new) .... 63.589 ± 0.038 mm (2.5035 ± .0015 in)
Maximum permissible clearance between bearing and bearing surface (journal) (worn) .... 0.18 mm (.007 in)

(2) Tight fit between the gear and camshaft .... 0.030 to 0.071 mm (.0012 to .0028 in)
Maximum permissible temperature of the gear for installation on the camshaft (do not use a torch) .. 315°C (600°F)

(3) End play for the camshaft .... 0.18 ± 0.08 mm (.007 ± .003 in)
Maximum permissible end play (worn) .... 0.51 mm (.020 in)

(4) Width of thrust groove in camshaft (new) .... 9.14 ± 0.05 mm (.360 ± .002 in)
Diameter of thrust pin (new) .... 8.97 ± 0.03 mm (.353 ± .001 in)
Torque for thrust pin .... 48 ± 7 N•m (35 ± 5 lb ft)

(5) Height of camshaft lobes.

To find lobe lift, use the procedure that follows:

A. Measure camshaft lobe height (5).

B. Measure base circle (7).

C. Subtract base circle (Step B) from lobe height (Step A). The difference is actual lobe lift (6).

D. Specified camshaft lobe lift (6) is:

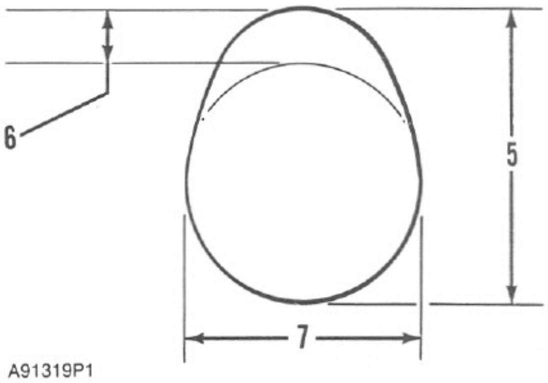
9N5230 Camshaft used with roller lifters:

a. Exhaust lobe .... 9.40 mm (.370 in)
b. Intake lobe .... 9.33 mm (.367 in)

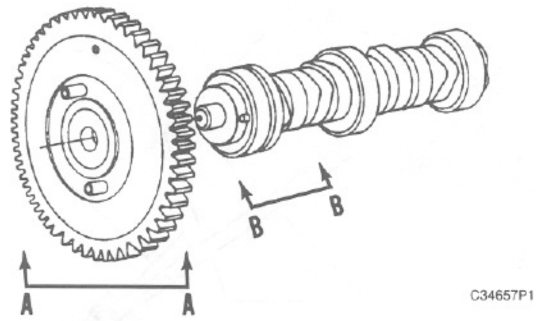
2W4238 Camshaft used with flat face lifters:

c. Exhaust lobe .... 9.40 mm (.370 in)
d. Intake lobe .... 9.06 mm (.357 in)

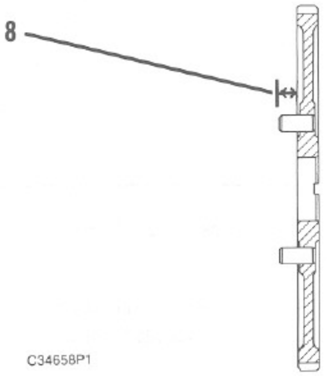
Maximum permissible difference between actual lobe lift (Step C) and specified lobe lift (Step D) is 0.25 mm (.010 in).



A91319P1

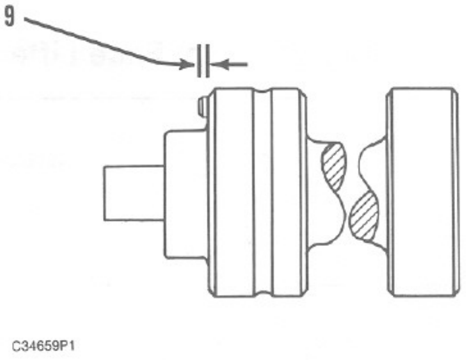


Camshaft Gear Assembly



View A-A

(8) Distance from the end of 9N5771 Dowel to the face of gear .... 11.81 ± 0.13 mm (.465 ± .005 in)



View B-B

(9) Distance from the end of 5P4283 Dowel to the face of camshaft .... 2.00 ± 0.25 mm (.079 ± .010 in)

Camshaft Installation

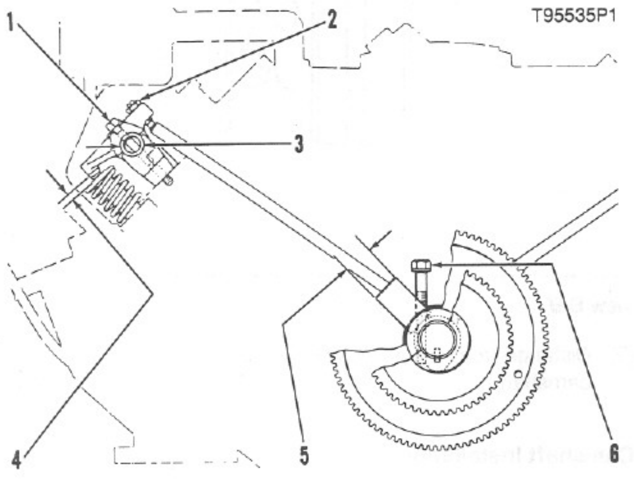
NOTE: For installation of camshaft, the timing mark on the camshaft gear tooth must be in alignment with the timing mark on the tooth space of the crankshaft gear.

Intake Valve Timing

1. Check the No. 1 intake valve clearance with the engine stopped. The valve clearance must be 0.30 to 0.46 mm (.012 to .018 in). If the valve clearance is not in this range, adjust the clearance to 0.38 mm (.015 in).
2. Mark Top Center Position of the crankshaft on the vibration damper or pulley.
3. Use a dial indicator to measure the intake valve movement.
4. Rotate the crankshaft in the direction of normal engine rotation. Stop when the intake valve is 1.91 mm (.075 in) off its seat in the opening sequence. At this point the crankshaft must be 10 ± 2° After Top Center.

Valve Rocker Arms And Lifters

For Engines That Have Flat Face Lifters



(1) Torque for bolts that hold rocker arms .... 24 ± 7 N•m (18 ± 5 lb ft)

(2) Torque for locknut for valve adjustment screw .... 30 ± 7 N•m (24 ± 5 lb ft)

(3) Diameter of the shaft for the rocker arms .... 21.793 to 21.814 mm (.8580 to .8588 in)

Minimum permissible diameter (worn) .... 21.768 mm (.8570 in)

Bore in bearings for the rocker arms (new) .... 21.852 ± 0.020 mm (.8603 ± .0008 in)

Maximum permissible bore (worn) .... 21.920 mm (.8630 in)

Maximum permissible clearance between bore in bearing and shaft (worn) .... 0.13 mm (.005 in)

(4) Clearance for valves (intake valve) ...... 0.38 mm (.015 in)

Clearance for valves (exhaust valve) ... 0.64 mm (.025 in)

(5) Diameter of cam follower .... 29.436 ± 0.010 mm (1.1589 ± .0004 in).

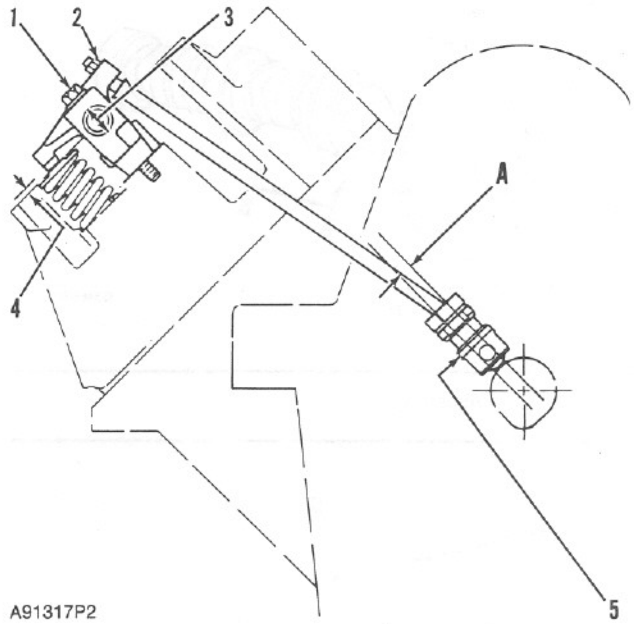
Minimum permissible diameter (worn) .... 29.401 mm (1.1575 in)

Bore in block for cam follower .... 29.525 ± 0.025 mm (1.1624 ± .0010 in)

Maximum permissible bore (worn) .... 29.591 mm (1.1650 in)

(6) Torque for the thrust pin for the camshaft .... 45 ± 7 N•m (35 ± 5 lb ft)

For Engines That Have Roller Lifters



1. Turn camshaft so cam lobe is opposite lifter bore.
2. Install guide spring on lifter.
3. Put lifter assembly in engine oil and install into lifter bore so that the tab on the guide spring is located within area (A).
4. Push lifter into bore until contact is made with camshaft.

(1) Torque for bolts that hold rocker arms .... 24 ± 7 N•m (18 ± 5 lb ft)

(2) Torque for locknut for valve adjustment screw .... 30 ± 7 N•m (24 ± 5 lb ft)

(3) Diameter of the shaft for the rocker arms .... 21.793 to 21.814 mm (.8580 to .8588 in)

Minimum permissible diameter (worn) .... 21.768 mm (.8570 in)

Bore in bearings for the rocker arms (new) .... 21.852 ± 0.020 mm (.8603 ± .0008 in)

Maximum permissible bore (worn) .... 21.920 mm (.8630 in)

Maximum permissible clearance between bore in bearing and shaft (worn) .... 0.13 mm (.005 in)

(4) Clearance for valves (intake valve) ...... 0.38 mm (.015 in)

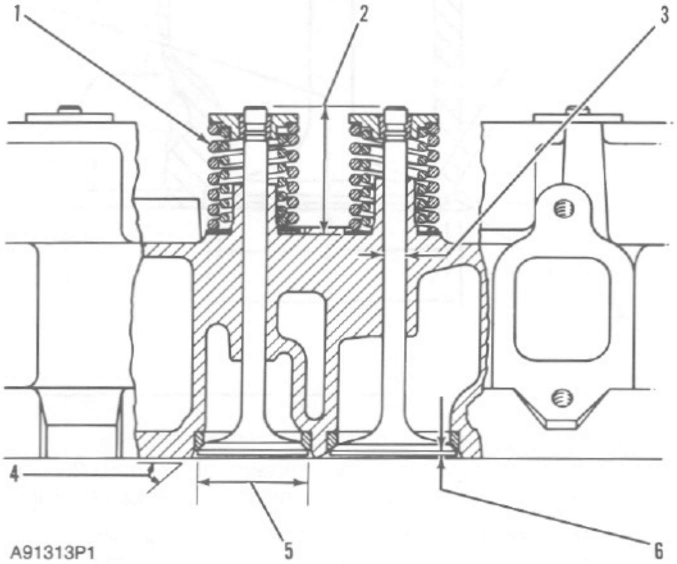
Clearance for valves (exhaust valve) ... 0.64 mm (.025 in)

(5) Diameter of lifter .... 29.464 ± 0.015 mm (1.1600 ± .0006 in)

Bore in block for lifter .... 29.525 ± 0.025 mm (1.1624 ± .0010 in)

Valves

NOTE: GUIDELINE FOR REUSABLE PARTS; VALVES AND VALVE SPRINGS, Forms SEBF8002 and SEBF8034, have the procedure and specifications necessary for checking used valves and valve springs.



A91313P1

(1) 9N5496 Spring for valves (outer):

Length under test force .... 45.47 mm (1.790 in)
Test force .... 185.0 ± 18.0 N (41.6 ± 4 lb)
Use again minimum load at length under test force .... 166 N (37.3 lb)
Length of spring at valve open position .... 30.23 mm (1.190 in)
Use again minimum load at valve open position .... 600 N (135 lb)
Free length after test .... 51.77 mm (2.038 in)
Outside diameter .... 39.62 mm (1.560 in)
Spring must not be bent more than ..... 1.80 mm (.071 in)

(1) 9N5495 Spring for valves (inner):

Length under test force .... 42.47 mm (1.672 in)
Test force .... 91.2 ± 9.0 N (20.5 ± 2 lb)
Use again minimum load at length under test force .... 81.9 N (18.4 lb)
Length of spring at valve open position .... 27.23 mm (1.072 in)
Use again minimum load at valve open position .... 295 N (66.3 lb)
Free length after test .... 48.77 mm (1.920 in)
Outside diameter .... 26.67 mm (1.050 in)
Spring must not be bent more than ..... 1.70 mm (.067 in)

(2) Distance from the end of the valve to the valve spring spacer seat .... 52.40 ± 0.38 mm (2.063 ± .015 in)

(3) Diameter of valve stem:

7C362 and 9L7682 Intake Valve .... 9.462 ± 0.013 mm (.3725 ± .0005 in)
Use again minimum diameter of the valve stem .... 9.42 mm (.371 in)
9L7683 and 9N5125 Exhaust Valve (tapered stem):
Head end of valve stem .... 9.411 ± 0.013 mm (.3705 ± .0005 in)
Use again minimum diameter of the head end of valve stem .... 9.37 mm (.369 in)
Lock end of valve stem .... 9.436 ± 0.013 mm (.3715 ± .0005 in)
Use again minimum diameter of the lock end of valve stem .... 9.408 mm (.3704 in)

Bore in the valve guides (intake and exhaust) .... 9.512 ± 0.013 mm (.3745 ± .0005 in)

Maximum permissible bore in the valve guides (worn):

Measure 19.0 mm (.75 in) deep in valve guide bore from both ends of the valve guide .... 9.550 mm (.3760 in)

(4) Angle of valve face:

Intake valve .... 30° ± 15'
Exhaust valve .... 45° ± 15'

(5) Diameter of valve head (intake valve) ... 53.19 ± 0.13 mm (2.094 ± .005 in)

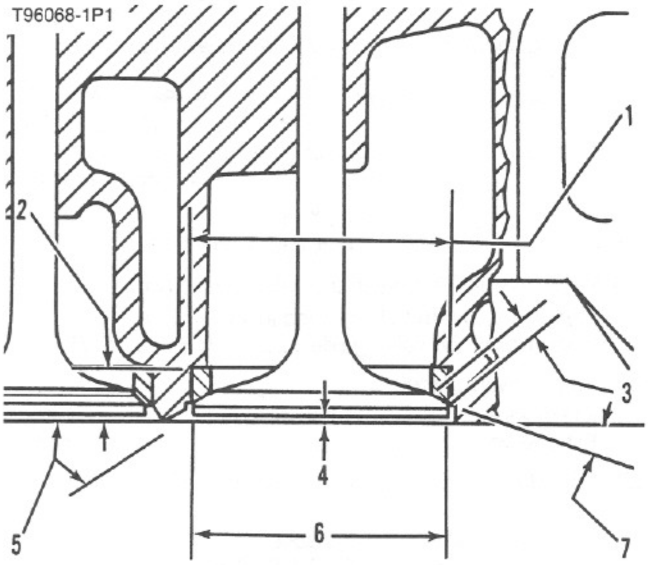
Diameter of valve head (exhaust valve) .... 45.82 ± 0.13 mm (1.804 ± .005 in)

(6) Thickness of valve lip:

Intake valve .... 2.31 mm (.091 in)
Use again minimum valve lip thickness .... 1.78 mm (.070 in)
Exhaust valve .... 1.60 mm (.063 in)
Use again minimum valve lip thickness .... 1.27 mm (.050 in)

c Valve Seats And Inserts

Intake Valve (with valve seat insert)



(1) Diameter of the valve seat insert ...... 54.610 ± 0.013 mm (2.1500 ± .0005 in)
Bore in head for valve seat insert ..... 54.534 ± 0.013 mm (2.1470 ± .0005 in)

(2) Depth of bore in head for valve seat insert .... 11.23 ± 0.05 mm (.442 ± .002 in)

(3) Maximum permissible width of the face of the valve seat insert .... 3.05 mm (.120 in)

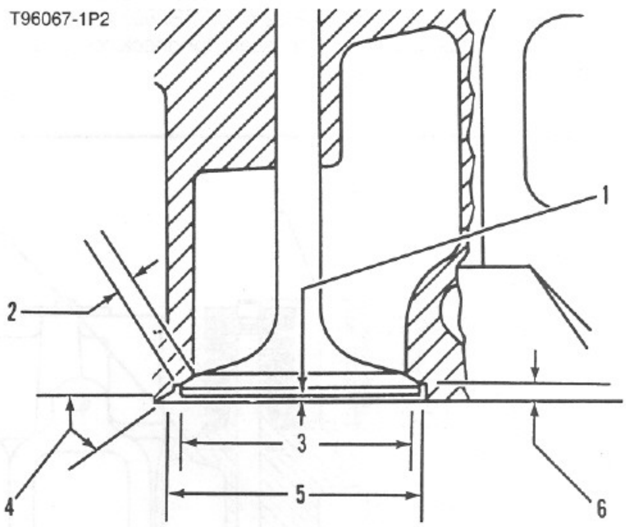
(4) Distance from head of valve to cylinder head face:
Maximum permissible (valve closed) ... 1.73 mm (.068 in)
Minimum permissible (valve closed) .... 0.91 mm (.036 in)

(5) Angle of the face of the valve seat insert .... 30 ½ ± ½°

(6) Outside diameter of the face of the valve seat insert .... 52.23 ± 0.13 mm (2.045 ± .005 in)
Maximum permissible .... 52.45 mm (2.065 in)

(7) Angle to grind face of seat insert (to get a reduction of maximum seat diameter) .... 15°

Intake Valve (without valve seat insert)



(1) Distance from head of valve to cylinder head face:
Maximum permissible (valve closed) ... 1.73 mm (.068 in)
Minimum permissible (valve closed) .... 0.91 mm (.036 in)

(2) Maximum permissible width of the face of the valve seat .... 3.05 mm (.120 in)

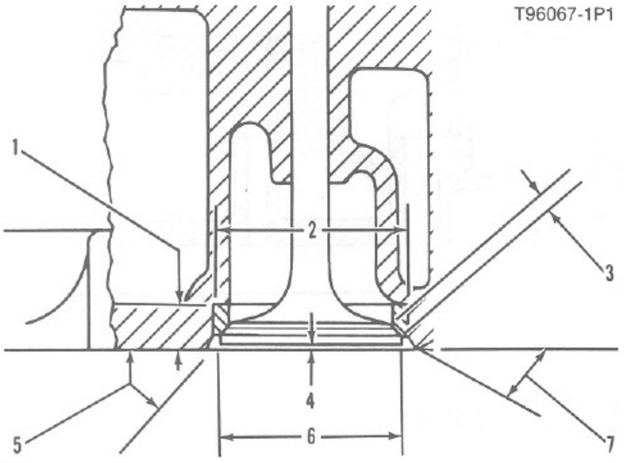
(3) Outside diameter of the valve seat .... 52.23 ± 0.13 mm (2.045 ± .005 in)
Maximum permissible .... 52.45 mm (2.065 in)

(4) Angle of the face of the valve seat .... 30 ½ ± ½°

(5) Diameter of the bore .... 54.61 mm (2.150 in)

(6) Maximum permissible depth of the bore to make the face of the valve seat smaller .... 4.32 mm (.170 in)

Exhaust Valve



(1) Depth of bore in head for valve seat insert .... 11.23 ± 0.13 mm (.442 ± .005 in)

(2) Diameter of valve seat insert .... 48.565 ± 0.013 mm (1.9120 ± .0005 in)

Bore in head for valve seat insert ..... 48.489 ± 0.013 mm (1.9090 ± .0005 in)

(3) Maximum permissible width of the face of the valve seat insert .... 2.67 mm (.105 in)

(4) Distance from head of valve to cylinder head face:

Maximum permissible (valve closed) ... 2.16 mm (.085 in)
Minimum permissible (valve closed) .... 1.27 mm (.050 in)

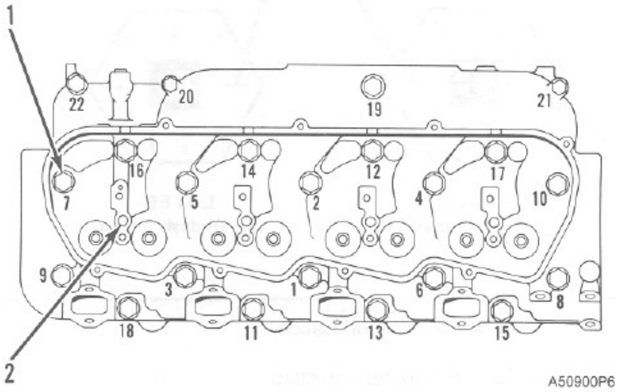
(5) Angle of the face of the valve seat insert .... 45 ½ ± ½°

(6) Outside diameter of the face of the valve seat insert .... 44.07 ± 0.13 mm (1.735 ± .005 in)

Maximum permissible .... 44.70 mm (1.760 in)

(7) Angle to grind face of seat insert (to get a reduction of maximum seat diameter) .... 15°

Cylinder Head



(1) Put 6V4876 Molykote Lubricant on bolt threads and tighten bolts according to the Head Bolt Torque Chart that follows:

Head Bolt Torque Chart

Tightening Procedure	Earlier Bolts (With Six Dash Marks)[1]	Later Bolts (With Seven Dash Marks)[1]
Step 1. Tighten bolts 1 through 18 in number sequence to:	130 ± 7 N•m (95 ± 5 lb ft)	150 ± 7 N•m (110 ± 5 lb ft)
Step 2. Loosen bolts 1 through 18 until the washers can be turned freely.		
Step 3. Tighten bolts 1 through 18 in number sequence to:	80 ± 14 N•m (60 ± 10 lb ft)	80 ± 14 N•m (60 ± 10 lb ft)
Step 4. Tighten bolts 1 through 18 in number sequence to:	130 ± 7 N•m (95 ± 5 lb ft)	150 ± 7 N•m (110 ± 5 lb ft)
Step 5. Again tighten bolts 1 through 10 in number sequence to:	130 ± 7 N•m (95 ± 5 lb ft)	165 ± 7 N•m (120 ± 5 lb ft)
Step 6. Tighten bolts 19 through 22 in number sequence to:	43 ± 7 N•m (32 ± 5 lb ft)	43 ± 7 N•m (32 ± 5 lb ft)

[1] See Illustration 1 for identification of EARLIER and LATER bolts.

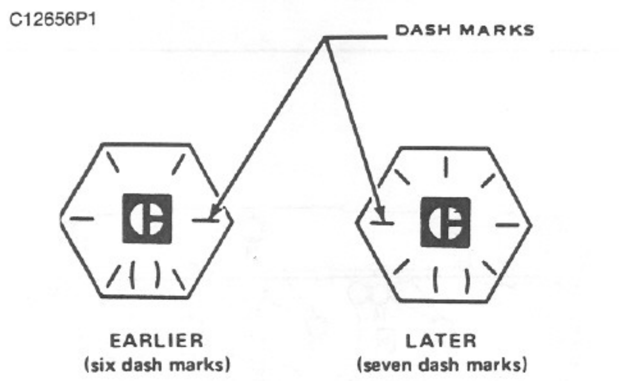


Illustration 1. Bolt head identification.

(2) Holes for fuel injection nozzles.

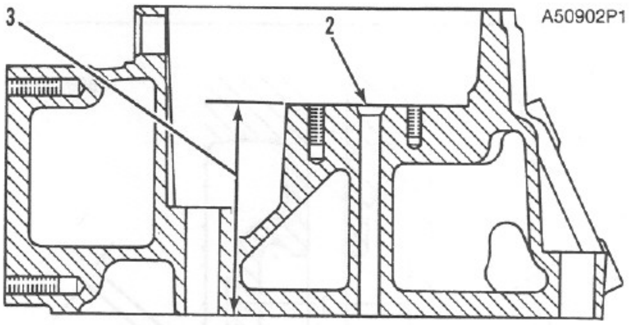
NOTICE

The higher cylinder head bolt torque may be used on earlier engines ONLY if the bolts are replaced with the later higher strength bolts (seven dash marks on the bolt head). If the earlier bolts are tightened to the later torque specification, they may yield (stretch) and lose their clamping force.

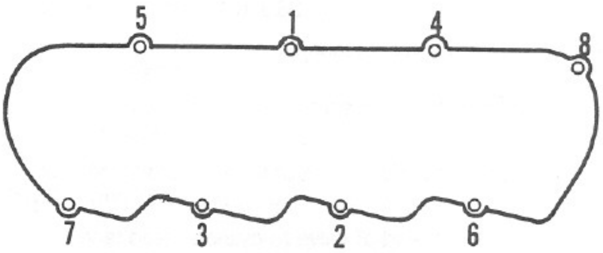
Head Bolt Location Chart

Dia.	Part No.	Location (Bolt No.)	Bolt Length "L"
½"	6F5282	5,2,4,10	133.4 mm (5.25 in)
	2B2006	7,9,3,1,6,8	120.6 mm (4.75 in)
	L1329	16,14,12,17	76.2 mm (3.00 in)
	2B947	18,11,13,15	57.2 mm (2.25 in)
	5B9603	19,20,21	127.0 mm (5.00 in)
⅜"	S1571	22	44.5 mm (1.75 in)

(3) Thickness of cylinder head (measure through the fuel injection nozzle holes at each end of the cylinder head).
New .... 96.14 ± 0.15 mm (3.785 ± .006 in)
Minimum permissible thickness .... 95.86 mm (3.774 in)
Flatness of the cylinder head should be within 0.15 mm (.006 in) total, and a maximum of 0.08 mm (.003 in) for any 152.4 mm (6 in) span.



Valve Covers



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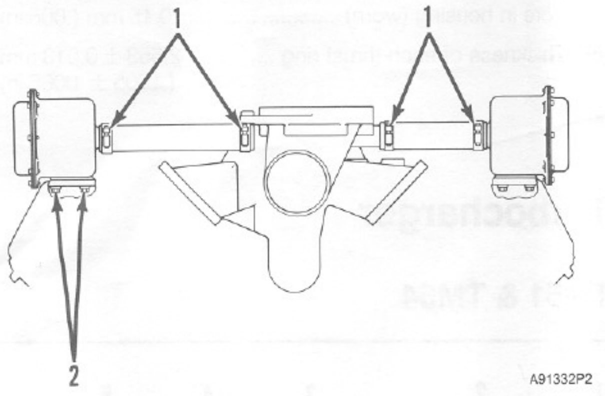
Tightening Sequence

(1) Tighten bolts in sequence shown to a torque of .... 14 ± 3 N•m (10 ± 2 lb ft)

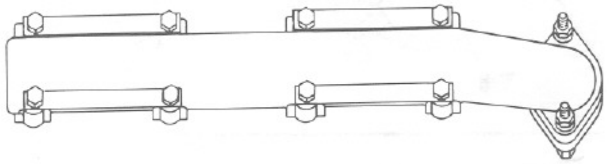
Crankcase Ventilation Valve



(1) Torque for hose clamps .... 2.3 ± 0.2 N•m (20 ± 2 lb in)

(2) Torque for bolts .... 3.4 ± 0.5 N•m (30 ± 4 lb in)

Exhaust Manifold



A91316P2

Put 5P3931 Anti-Seize Compound on threads of bolts.

Torque for bolts...43 ± 7 N•m (32 ± 5 lb ft)

Locks must be bent on a flat side of the bolt head. Bolts must be turned no more than 30° (in the direction of increased torque only) for the alignment of locks with a flat side of the bolt head.

Turbocharger Impeller Installation

(Schwitzer Only)

Installation Procedure

A. Put 6V1541 Quick Cure Primer on the nut and the shaft threads to clean them, if necessary.

B. Put a small amount of 9S3265 Retaining Compound on the nut and shaft threads.

NOTICE

Do not let the retaining compound get into the compressor wheel bore or on the shaft, because it can make removal of the compressor wheel difficult during future turbocharger disassembly.

C. Put a small amount of lubricant, such as Lubriplate, on the nut seat area on the compressor. Do not put lubrication on the threads.

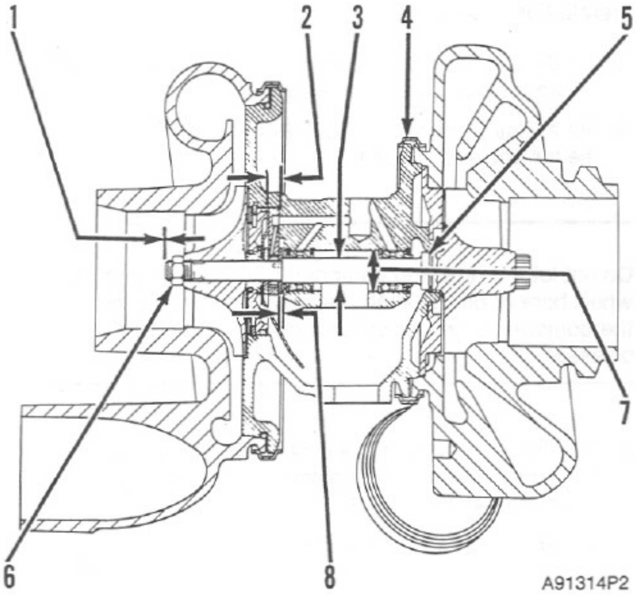
D. Tighten the compressor wheel retainer nut to .... 28 ± 3 N•m (22 ± 2 lb ft)

NOTICE

Do not bend or add stress to the shaft when nut is loosened or tightened.

Turbocharger

4TF555 & 4TF606



(1) End play for shaft (new) .... 0.114 ± 0.038 mm (.0045 ± .0015 in)

Maximum permissible end play (worn) .... 0.20 mm (.008 in)

(2) Thickness of thrust bearing .... 5.36 ± 0.03 mm (.211 ± .001 in)

(3) Diameter of surface on shaft (journal) for the bearing (new) .... 14.254 to 14.262 mm (.5612 to .5615 in)

Bore in the bearing (new) .... 14.293 to 14.300 mm (.5627 to .5630 in)

Maximum permissible clearance between bearing and shaft (worn) .... 0.08 mm (.003 in)

(4) Put 5P3931 Anti-Seize Compound on threads and tighten bolt holding band clamp to .... 13.6 N•m (120 lb in)

(5) Maximum permissible gap of oil seal ring, measured in bore of housing .... 0.23 mm (.009 in)

(6) Nut for impeller (See Turbocharger Impeller Installation).

NOTICE

Do not bend or add stress to the shaft when nut is loosened or tightened.

(7) Bore in housing (new) .... 22.255 to 22.268 mm (.8762 to .8767 in)

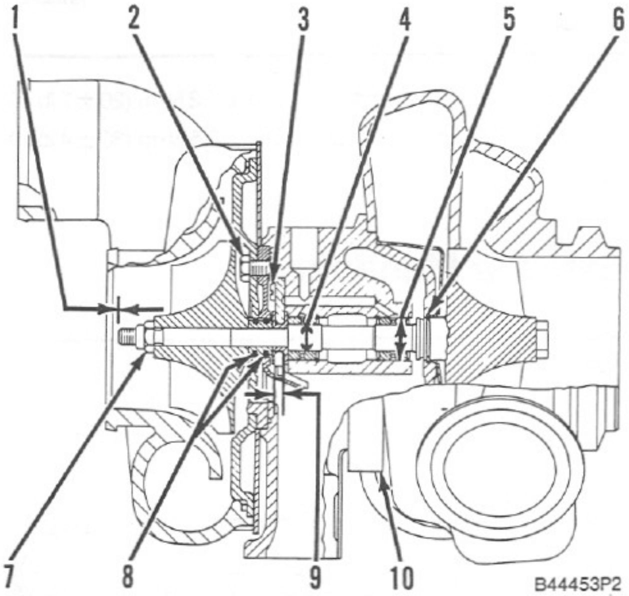
Outside diameter of the bearing (new) .... 22.144 to 22.154 mm (.8718 to .8722 in)

Maximum permissible clearance between bearing and bore in housing (worn) .... 0.15 mm (.006 in)

(8) Thickness of each thrust ring .... 2.553 ± 0.013 mm (.1005 ± .0005 in)

Turbocharger

TM51 & TM54



(1) End play for shaft (new) .... 0.051 to 0.081 mm (.0020 to .0032 in)

(2) Tighten bolts that hold back plate to bearing housing to .... 9.5 ± 1 N•m (84 ± 9 lb in)

(3) Tighten screws that hold thrust bearing to .... 2.5 ± 0.2 N•m (22 ± 2 lb in)

(4) Diameter of surface on shaft (journal) for the bearing (new) .... 12.992 to 13.000 mm (.5115 to .5118 in)

Bore in the bearing (new) .... 13.028 to 13.038 mm (.5129 to .5133 in)

(5) Bore in housing (new) .... 20.175 to 20.188 mm (.7943 to .7948 in)

Outside diameter of the bearing (new) .... 20.069 to 20.081 mm (.7901 to .7906 in)

(6) Turbine end oil seal ring, end gap when installed in a bore of 20.90 mm (.823 in) .... 0.10 to 0.38 mm (.004 to .015 in)

(7) Put 2P2506 Thread Lubricant on the shaft threads and on the nut face and tighten nut to .... 4 N•m (35 lb in)
Tighten nut more .... 120°

NOTICE

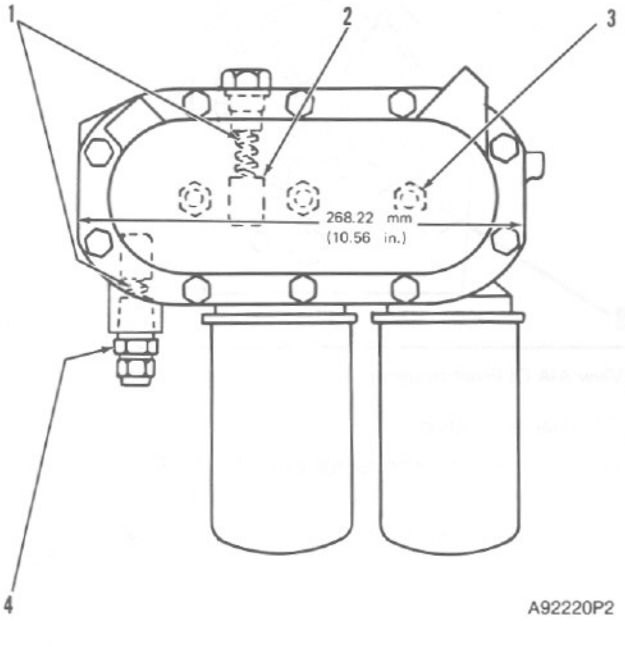
Do not bend or add stress to the shaft when nut is loosened or tightened.

(8) Impeller end oil seal ring, end gap when installed in a bore of 17.463 mm (.6875 in) .... 0.08 to 0.38 mm (.003 to .015 in)

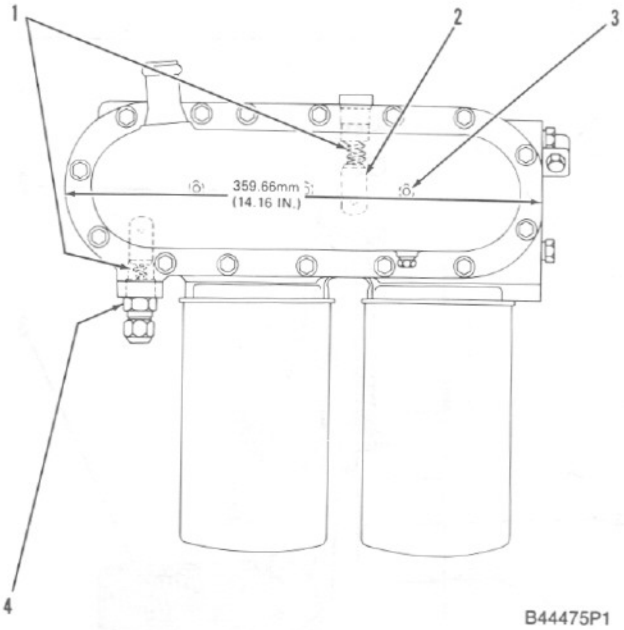
(9) Thickness of thrust bearing .... 4.359 to 4.369 mm (.1716 to .1720 in)

(10) Put 5P3931 Anti-Seize Compound on threads and tighten bolt holding band clamp to .... 14 ± 1 N•m (120 ± 12 lb in)

Engine Oil Cooler And Filter



Earlier



Later

Oil pressure difference that makes the oil filter bypass valve open .... 140 ± 25 kPa (20 ± 4 psi)

Oil pressure difference that makes the oil cooler bypass valve open .... 125 ± 25 kPa (18 ± 4 psi)

(1) 9L9188 Spring (oil cooler and oil filter bypass valve):
    Length under test force .... 43.2 mm (1.70 in)
    Test force .... 15.6 N (3.5 lb)
    Free length after test .... 57.9 mm (2.28 in)
    Outside diameter .... 11.18 mm (.440 in)

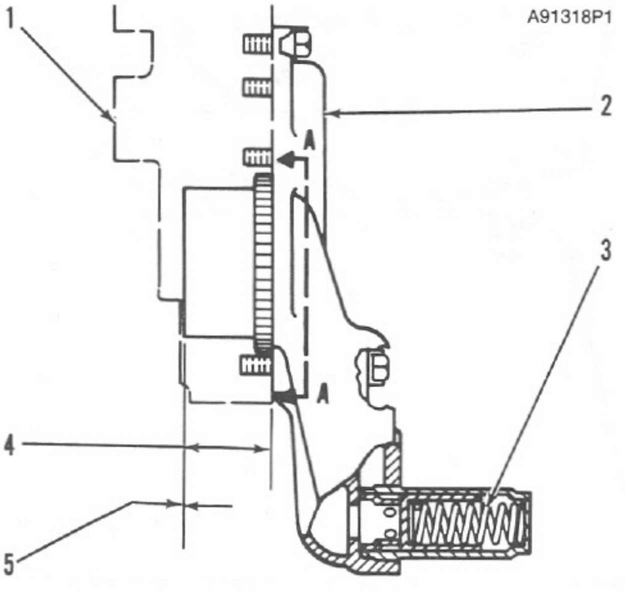
(2) Oil filter bypass valve.

(3) Torque for nuts that hold oil cooler core to oil cooler base (hand torque only) .... 22 ± 3 N•m (16 ± 2 lb ft)

NOTE: If applicable, assemble gasket to oil cooler base with indexing point toward the front of the engine and in the up position.

(4) Oil cooler bypass valve.

Oil Pump



NOTE: Tighten relief valve guide to .... 40 ± 7 N•m (30 ± 5 lb ft)

(1) Front housing assembly.

(2) Oil pump cover assembly.

(3) 1W1788 Spring (pump pressure relief valve):

Length under test force .... 59.94 mm (2.360 in)
Test force .... 314 ± 14 N (71 ± 3 lb)
Free length after test .... 78.23 mm (3.080 in)
Outside diameter .... 22.23 mm (.875 in)

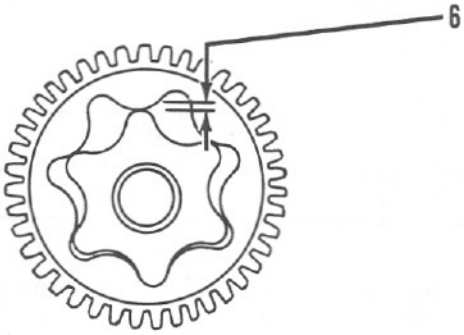
(3) 1W2208 Spring (pump pressure relief valve):

Length under test force .... 59.94 mm (2.360 in)
Test force .... 290 ± 14 N (65 ± 3 lb)
Free length after test .... 85.85 mm (3.380 in)
Outside diameter .... 22.23 mm (.875 in)

(4) Width of oil pump rotors (new) .... 36.474 ± 0.008 mm (1.4360 ± .0003 in)

Depth of counterbore in front housing (new) .... 36.576 ± 0.025 mm (1.4400 ± .0010 in)

(5) Maximum permissible end clearance of oil pump rotors when measured with oil pump installed to front cover .... 0.15 mm (.006 in)



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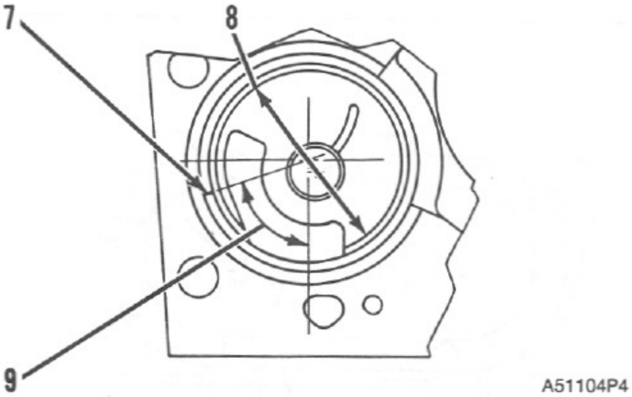
View A-A Of Rotor Oil Pump

(6) Clearance of oil pump rotor tip when measured with oil pump installed to front cover .... 0.05 to 0.20 mm (.002 to .008 in)

Maximum permissible clearance of oil pump rotor tip .... 0.28 mm (.011 in)



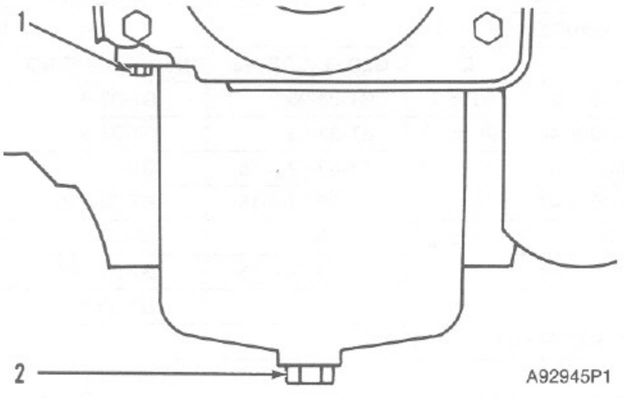
View A-A Of Front Housing

(7) Bearing junction.

(8) Diameter of bearing for rotor (new) ... 71.224 ± 0.056 mm (2.8041 ± .0022 in)

(9) Position of main bearing junction from vertical centerline .... 75 ± 30°

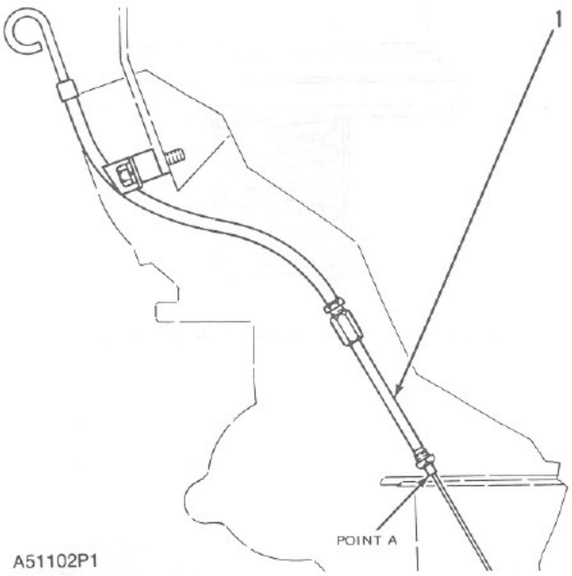
Oil Pan



(1) Torque for bolts that hold oil pan .... 23 ± 4 N•m (17 ± 3 lb ft)

(2) Torque for oil pan drain plug .... 70 ± 14 N•m (50 ± 10 lb ft)

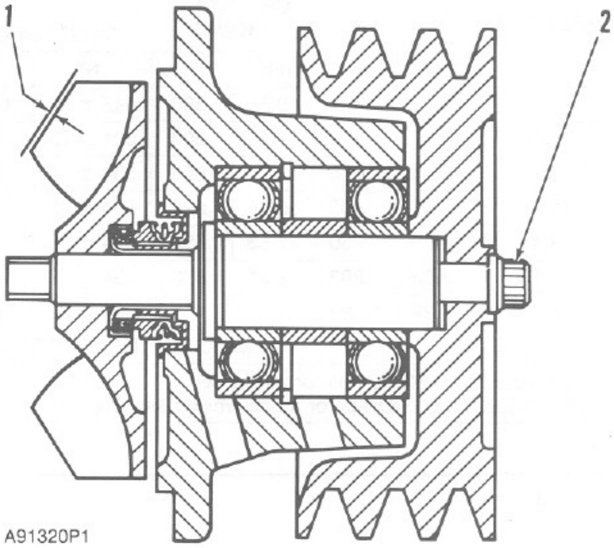
Oil Level Gauge



(1) Guide assembly.

Assemble lower part of guide assembly (1) so that Point A is even with bottom surface of block within ± 0.8 mm (± .03 in)

Water Pump



NOTE: The outer bearing O.D. and housing bore must be free of oil before assembling bearing into housing. After assembly, apply 4C9508 Sealant-Wicking to the chamfer area only. Remove excess sealant.

Alternate sealant: Put 9S3263 Thread Lock on outer bearing O.D. and housing bore before assembly.

(1) Clearance between the water pump impeller face and front cover .... 0.28 to 0.84 mm (.011 to .033 in)

(2) Torque for pulley .... 75 ± 7 N•m (55 ± 5 lb ft)

BELT TENSION CHART

BELT SIZE	WIDTH BELT TOP		WIDTH TOP OF PULLEY GROOVE		BELT TENSION "INITIAL"* GAUGE READING		BELT TENSION "USED"** GAUGE READING		BORROUGHS GAUGE NUMBERS	
	mm	in.	mm	in.	N	lb	N	lb	OLD GAUGE NO.	NEW GAUGE NO.
3/8	10.72	.422	9.65	.380	445 ± 22	100 ± 5	400 ± 22	90 ± 5	BT-33-95	BT-33-97
1/2	13.89	.547	12.70	.500	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-95	BT-33-97
5V	15.88	.625	15.24	.600	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-72-4-15	BT-33-72C
11/16	17.48	.688	15.88	.625	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-72-4-15	BT-33-72C
3/4	19.05	.750	17.53	.690	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-72-4-15	BT-33-72C
15/16	23.83	.983	22.30	.878	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-72-4-15	BT-33-72C
8K	27.92	1.099			800 ± 22	180 ± 5	489 ± 44	110 ± 10		BT-33-109

MEASURE TENSION OF BELT FARTHEST FROM THE ENGINE

*"INITIAL" BELT TENSION is for a new belt.
**"USED" BELT TENSION is for a belt which has more than 30 minutes of operation at rated speed of engine.

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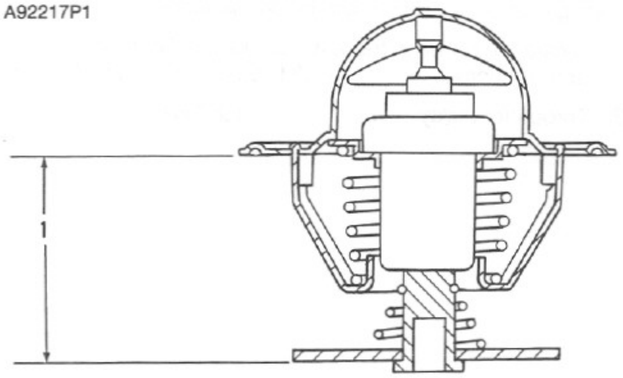
Water Temperature Regulators

9N5121 And 7C3472 Temperature Regulators

A92217P1

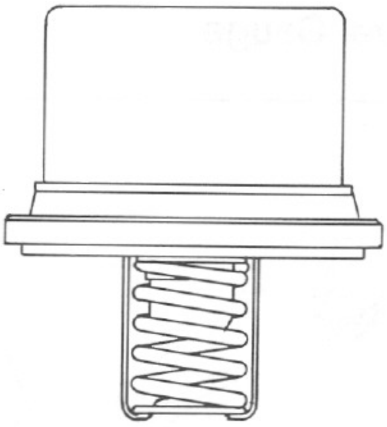


Temperature when completely open:

9N5121 Water Temperature Regulator .... 92°C (197°F)
7C3472 Water Temperature Regulator .... 98°C (208°F)

(1) Distance at completely open temperature must not be more than .... 37.85 mm (1.490 in)

9N3711 Temperature Regulator



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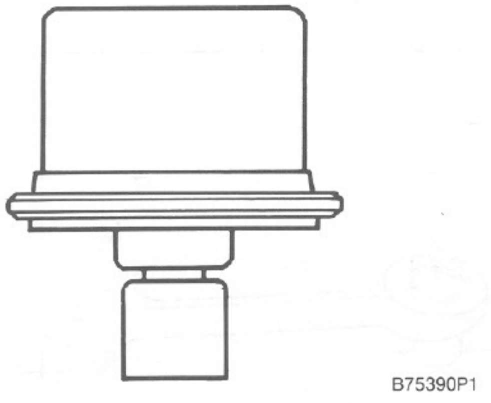
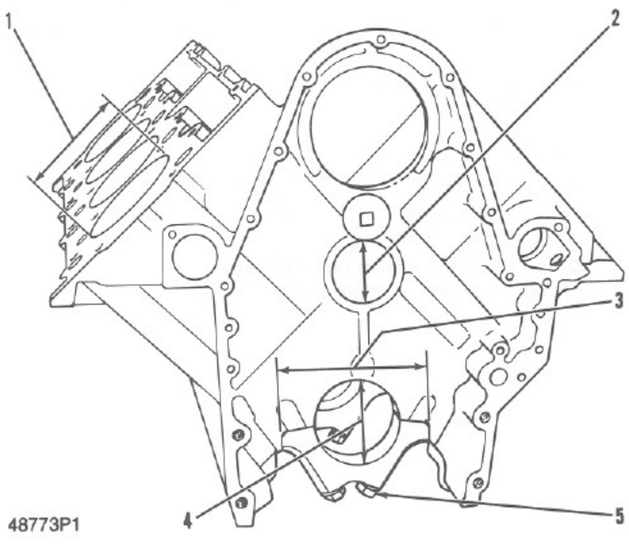


Temperature when completely open:

9N3711 Water Temperature Regulator .... 92°C (197°F)

Minimum completely open distance .... 9.53 mm (.375 in)

Cylinder Block



Measure wear of the cylinder bore at the top and bottom of piston ring travel.

(1) Cylinder bore [standard, original size] .... 114.300 to 114.338 mm (4.5000 to 4.5015 in)

The recommendation is made to make the cylinder bore the next size larger when the size of the bore is .... 114.452 mm (4.5060 in)

Cylinder bore must be made the next size larger when the size of the bore is .... 114.529 mm (4.5090 in)

Cylinder bore [0.51 mm (.020 in) larger than the original size] .... 114.821 ± 0.013 mm (4.5205 ± .0005 in)

The recommendation is made to make the cylinder bore the next size larger when the size of the bore is .... 114.960 mm (4.5260 in)

Cylinder bore must be made the next size larger when the size of the bore is .... 115.037 mm (4.5290 in)

Cylinder bore [1.02 mm (.040 in) larger than the original size] .... 115.329 ± 0.013 mm (4.5405 ± .0005 in)

Maximum permissible wear of cylinder bores (replacement of the cylinder block is necessary) .... 115.545 mm (4.5490 in)

(2) Bore in block for camshaft bearing .. 67.374 ± 0.013 mm (2.6525 ± .0005 in)

NOTE: Install camshaft bearings with the oil hole toward the top of the cylinder block.

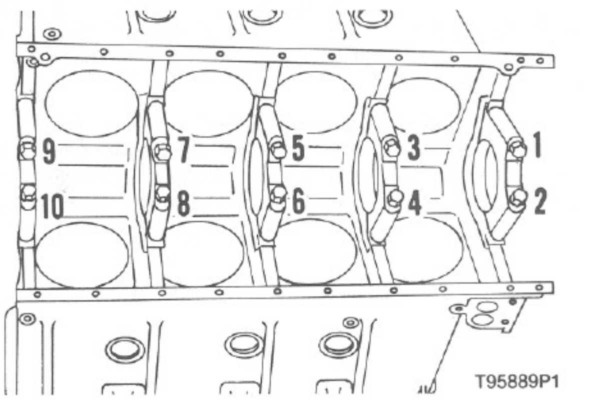
(3) Width of main bearing cap .... 166.624 ± 0.018 mm (6.5600 ± .0007 in)

Minimum permissible width of main bearing cap .... 166.573 mm (6.5580 in)

Width of main bearing cap guide (in cylinder block) .... 166.599 ± 0.013 mm (6.5590 ± .0005 in)

(4) Bore in block for main bearing .... 94.171 ± 0.013 mm (3.7075 ± .0005 in)

Permissible amount of distortion in bore .... 94.13 to 94.21 mm (3.706 to 3.709 in)



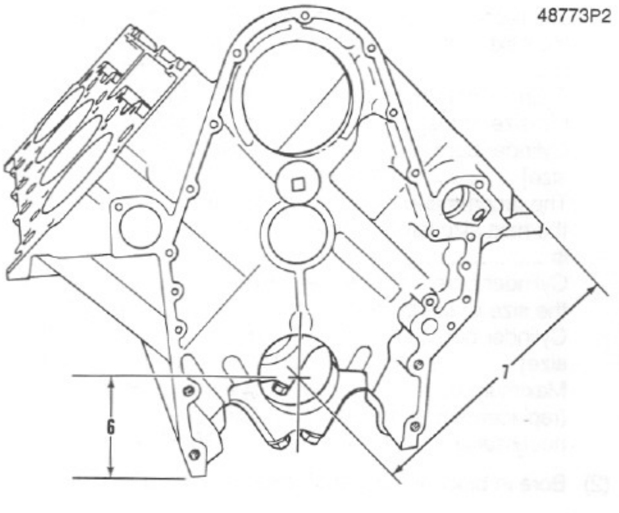
(5) Torque for bolts holding caps for main bearings:

a. Put 2P2506 Thread Lubricant on bolt threads and washer face.

b. Tighten all bolts in number sequence to .... 40 ± 4 N•m (30 ± 3 lb ft)

c. Put a mark on each bolt and cap.

d. Tighten all bolts in number sequence from mark .... 120 ± 5°



(6) Dimension (new) from centerline of crankshaft bearing bore to bottom of block (pan rails) ... 95.250 ± 0.038 mm (3.7500 ± .0015 in)

(7) Dimension (new) from centerline of crankshaft bearing bore to top of block (top deck) .... 322.66 ± 0.13 mm (12.703 ± .005 in)

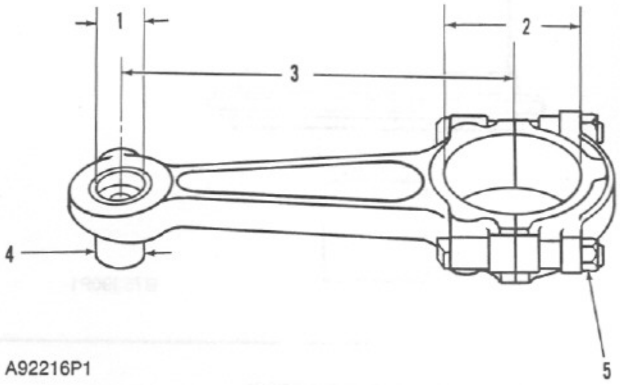
NOTICE

There are holes in the bores for the main bearings, between the cylinders for piston cooling orifices. These holes must have orifices or plugs installed or low oil pressure will be the result.

If the base for the oil cooler is 357.2 mm (14.06 in) long the engine has piston cooling orifices installed. If the base for the oil cooler is 268.2 mm (10.56 in) long the engine has plugs installed.

Piston cooling orifices were eliminated from 3208 truck engines effective with truck engine 2Z30692 with a rating of 150 KW (200 hp) @ 2000 rpm or 160 KW (215 hp) @ 2200 rpm. On earlier engines with these ratings the piston cooling orifices may continue to be used or replaced with 7N4953 Plugs.

c Connecting Rod



(1) Bore in bearing for piston pin .... 38.135 ± 0.008 mm (1.5014 ± .0003 in)

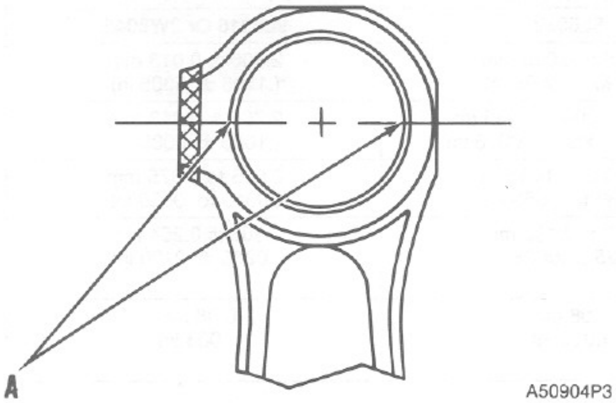
(2) Bore in connecting rod for bearing [when tightened according to procedure shown in (5)] .... 74.721 ± 0.013 mm (2.9418 ± .0005 in)

(3) Distance between center of bearing for piston pin and center of bearing for crankshaft journal .... 200.66 ± 0.03 mm (7.900 ± .001 in)

(4) Diameter of piston pin .... 38.097 ± 0.005 mm (1.4999 ± .0002 in)

Maximum permissible clearance between bearing and piston pin .... 0.08 mm (.003 in)

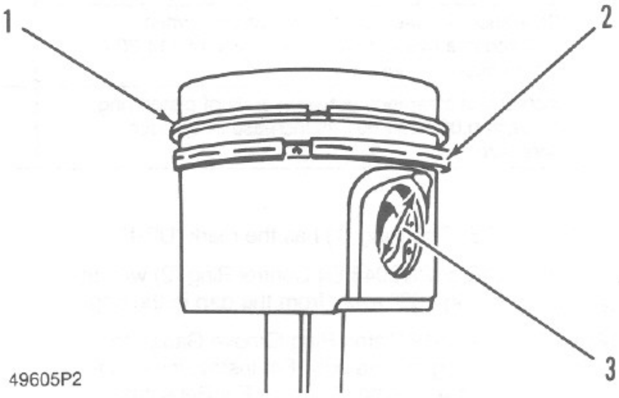
(5) Torque for nuts:
   a. Put 2P2506 Thread Lubricant on bolt threads and seating faces of cap and nut.
   b. Tighten both nuts to .... 40 ± 4 N•m (30 ± 3 lb ft)
   c. Put a mark on each nut and cap.
   d. Tighten each nut from mark .... 60 ± 5°



NOTE: Piston pin bearing junction and locating notch must be assembled in the top half of rod eye. Location of bearing junction to be within ± 5° of center line "A".

c Pistons And Rings (two ring piston)

Make reference to Guideline For Reusable Parts: Pistons, Form No. SEBF8049.



Pistons And Piston Rings		
	(1) Top Ring	(2) Oil Control Ring*
	9L6233	9L9316 Or 2W8045
Width of groove in piston for piston ring (new).	3.276 ± 0.013 mm (.1290 ± .0005 in)	2.806 ± 0.013 mm (.1105 ± .0005 in)
Thickness of piston ring (new).	3.150 + 0.000 − 0.038 mm (.1240 + .0000 − .0015 in)	2.756 ± 0.013 mm (.1085 ± .0005 in)
Clearance between groove and piston ring (new).	0.076 to 0.140 mm (.0030 to .0055 in)	0.025 to 0.076 mm (.0010 to .0030 in)
Clearance between ends of piston ring when installed in a cylinder with a bore size of 114.300 mm (4.5000 in) (new).	0.572 ± 0.190 mm (.0225 ± .0075 in)	0.508 ± 0.254 mm (.0200 ± .0100 in)
Increase in clearance between ends of piston ring for each 0.03 mm (.001 in) increase in cylinder bore size.	0.08 mm (.003 in)	0.08 mm (.003 in)

NOTE: 9L6233 Top Ring (1) has the mark "UP-1".

*Install 9L9316 or 2W8045 Oil Control Ring (2) with the gap in the spring 180° away from the gap in the ring.

NOTE: Use 5P3519 Piston Ring Groove Gauge to check the top ring groove only. For instructions on the use of the gauge, see the Guideline For Reusable Parts; Pistons, Form No. SEBF8049.

NOTE: Two different pistons are used in 3208 Truck engines. One piston has a crater volume of 53.7 ± 1.2 cm^3 (3.28 ± .07 in^3), and the other piston has a crater volume of 58.8 ± 1.2 cm^3 (3.59 ± .07 in^3). Check the part number stamped on the top of the piston, and refer to the parts book to be sure the correct replacement piston is used.

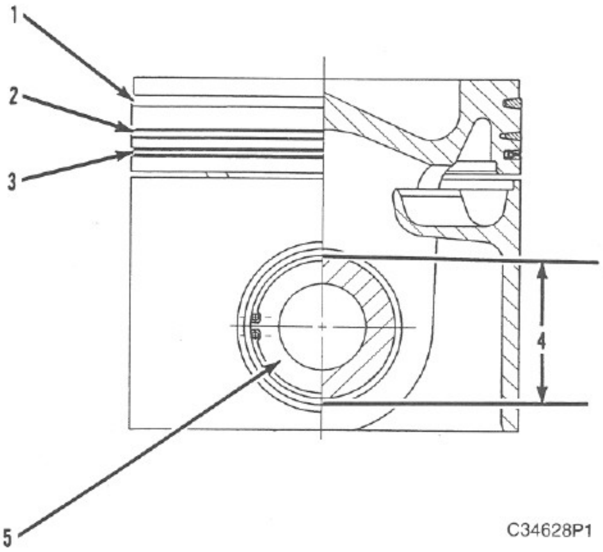
Piston Pin Bore

(3) Bore in piston for pin .... 38.123 to 38.133 mm (1.5009 to 1.5013 in)

Clearance between pin and bore in piston (new) .... 0.020 to 0.040 mm (.0008 to .0016 in)

Maximum permissible clearance between piston pin and bore in piston (worn) .... 0.08 mm (.003 in)

c Pistons And Rings (three ring piston)



Make reference to Guideline For Reusable Parts, Pistons, Form No. SEBF8049, and Guideline For Reusable Parts, Piston Pins And Retaining Rings, Form No. SEBF8051.

Top And Intermediate Ring

The 1U6431 Keystone Piston Ring Groove Gauge is necessary for measuring ring grooves in keystone style pistons. For correct use of the gauge group, refer to SEES5678 Instruction Card that is with the gauge group.

Install piston rings with "UP" side toward top of piston.

(1) Top ring has the mark "UP-1".

(2) Intermediate ring has the mark "UP-2".

Clearance between ends of piston ring when installed in a cylinder liner with a bore size of 114.30 mm (4.500 in)

Top and intermediate rings .... 0.572 ± 0.190 mm (.0225 ± .0075 in)

Increase in clearance between ends of piston rings for each 0.03 mm (.001 in) increase in cylinder liner bore size .... 0.08 mm (.003 in)

Oil Control Ring

(3) Install oil control ring with the gap in the spring 180 ± 45° away from the gap in the ring.

The 5P3519 Piston Ring Groove Gauge is available for checking ring grooves with straight sides. For instructions on the use of the gauge, refer to Guideline For Reusable Parts, Pistons, Form No. SEBF8049.

Width of groove in piston for piston ring (new) .... 2.806 ± 0.013 mm (.1105 ± .0005 in)

Thickness of piston ring (new) .... 2.756 ± 0.013 mm (.1085 ± .0005 in)

Clearance between groove and piston ring (new) .... 0.025 to 0.076 mm (.0010 ± .0030 in)

Clearance between ends of piston ring when installed in a cylinder liner with a bore size of 114.30 mm (4.500 in) .... 0.505 ± 0.255 mm (.0199 ± .0100 in)

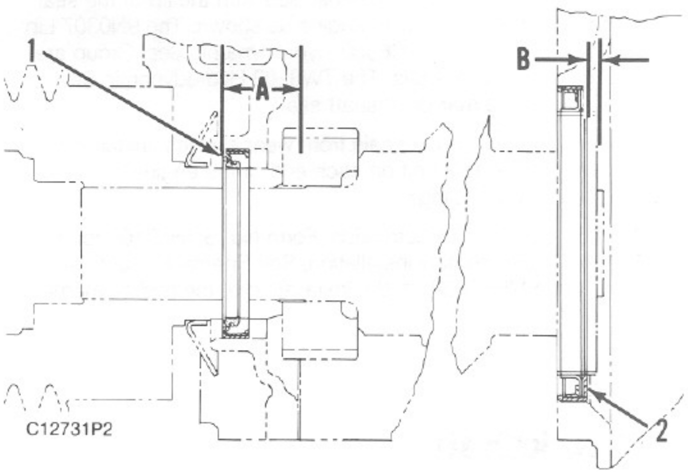
Increase in clearance between ends of piston ring for each 0.03 mm (.001 in) increase in cylinder liner bore size .... 0.08 mm (.003 in)

Piston Pin Bore

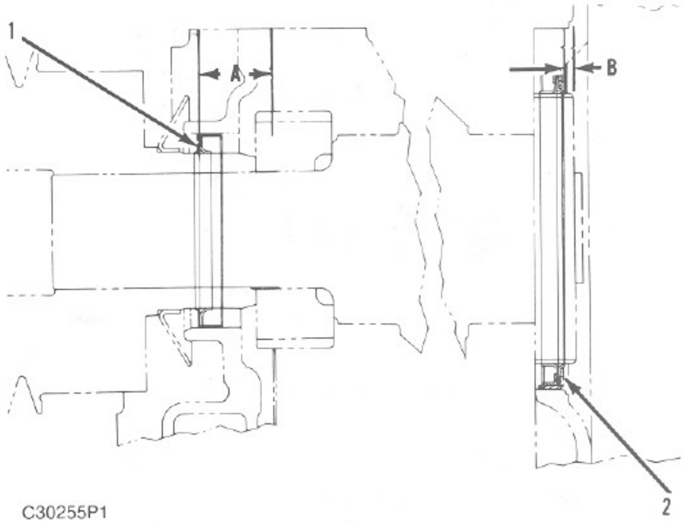
(4) Bore in piston for pin .... 38.123 to 38.133 mm (1.5009 to 1.5013 in)

(5) Pin diameter ...... 38.097 ± 0.005 mm (1.4998 ± .0002 in)
Clearance between pin and bore in piston (new) .... 0.020 to 0.040 mm (.0008 to .0016 in)
Maximum permissible clearance between piston pin and bore in piston (worn) .... 0.08 mm (.003 in)

c Crankshaft Seals



9N0542 Crankshaft Seal Group
(1) 9N0307 Lip Type Seal. (2) 7W3200 Hydrodynamic Seal Group.



9N0542 Crankshaft Seal Group
(1) 7C6660 Hydrodynamic Type Seal. (2) 7W3200 Hydrodynamic Seal Group.

(A) The distance from the edge of seal (1) to the gasket surface of the front housing is .... 38.10 ± 0.50 mm (1.500 ± .020 in)

(B) The distance from the edge of the hydrodynamic seal (3) to the edge of the wear sleeve is .... 4.30 ± 0.25 mm (.169 ± .010 in)

Remove front and rear seal groups as follows:

a. Use the 1P3075 Puller Group to remove the seals.
b. Use the 5P7318 Distorter Group to remove the wear sleeves.

NOTE: Seals and wear sleeves can not be used again after the seals and wear sleeves are separated.

Install front and rear seal groups as follows:

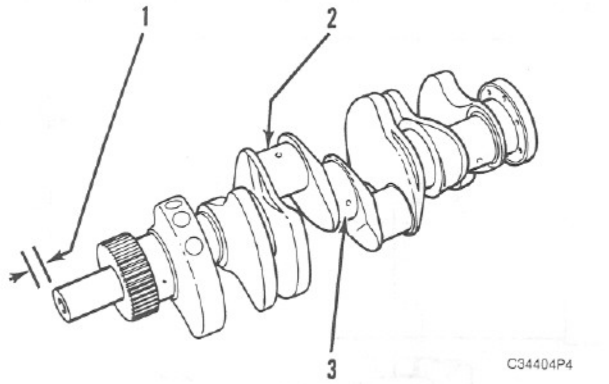
a. Clean the outer surface of the crankshaft with 6V1541 Quick Cure Primer.

b. Crankshaft seals must be installed with the lip of the seal toward the inside of the engine as shown. The 9N0307 Lip Type Seal and the 7C6660 Hydrodynamic Seal Group are front crankshaft seals. The 7W3200 Hydrodynamic Seal Group is the rear crankshaft seal.

c. Do not separate the seals from wear sleeves. Install the seal groups as a unit on each end of the engine as shown with correct tooling.

NOTE: See Special Instruction, Form No. SMHS7100 for the lip type seal assembly installation. See Special Instruction, Form No. SMHS8508 for the installation of the hydrodynamic seals.

c Crankshaft



Heat gear to install. Do not heat to a temperature of more than 260°C (500°F).

(1) End play for the crankshaft .... 0.08 to 0.25 mm (.003 to .010 in)

Maximum permissible end play for the crankshaft (worn) .... 0.36 mm (.014 in)

(2) Make reference to Bearings For Connecting Rods And Mains.

(3) Make reference to Bearings For Connecting Rods And Mains.

NOTE: See Reconditioning Procedures for the correct method to check for bent crankshafts.

c Bearings For Connecting Rods And Mains

Make reference to Guidelines For Reusable Parts: Main Bearings And Connecting Rod Bearings, Form No. SEBF8009.

CONNECTING ROD BEARINGS	
Original Size Journal	69.840 ± 0.015 mm (2.7496 ± .0006 in)
Undersize Journal 0.25 mm (.010 in)	69.586 ± 0.015 mm (2.7396 ± .0006 in)
Undersize Journal 0.51 mm (.020 in)	69.332 ± 0.015 mm (2.7296 ± .0006 in)
Undersize Journal 1.27 mm (.050 in)	68.570 ± 0.015 mm (2.6996 ± .0006 in)

Clearance between bearing and journal (new) .... 0.053 to 0.140 mm (.0021 to .0055 in)

Maximum permissible clearance between bearing and journal .... 0.15 mm (.006 in)

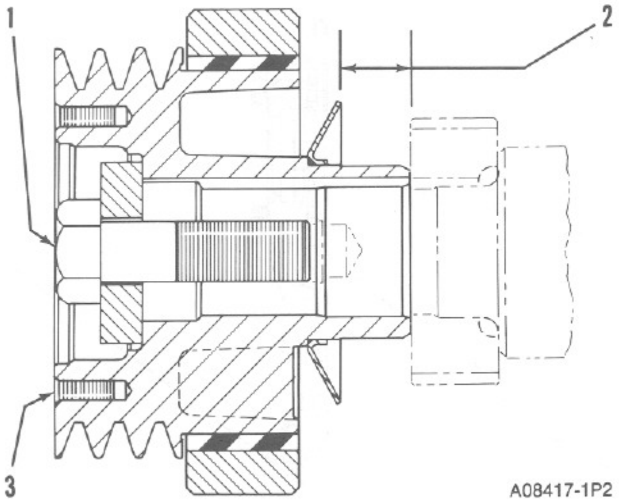
MAIN BEARINGS	
Original Size Journal	88.887 ± 0.015 mm (3.4995 ± .0006 in)
Undersize Journal 0.25 mm (.010 in)	88.633 ± 0.015 mm (3.4895 ± .0006 in)
Undersize Journal 0.51 mm (.020 in)	88.379 ± 0.015 mm (3.4795 ± .0006 in)
Undersize Journal 1.27 mm (.050 in)	87.617 ± 0.015 mm (3.4495 ± .0006 in)

Clearance between bearing and journal (new) .... 0.076 to 0.168 mm (.0030 to .0066 in)

Maximum permissible clearance between bearing and journal .... 0.18 mm (.007 in)

Pulley And Damper

Install the damper assembly on the crankshaft until the hub of the damper assembly comes in contact with the gear on the crankshaft. DO NOT use the bolt and washer that holds the damper assembly on the crankshaft to install the damper assembly.



A08417-1P2

(1) Torque for bolt that holds the pulley .... 624 ± 80 N•m (460 ± 60 lb ft)

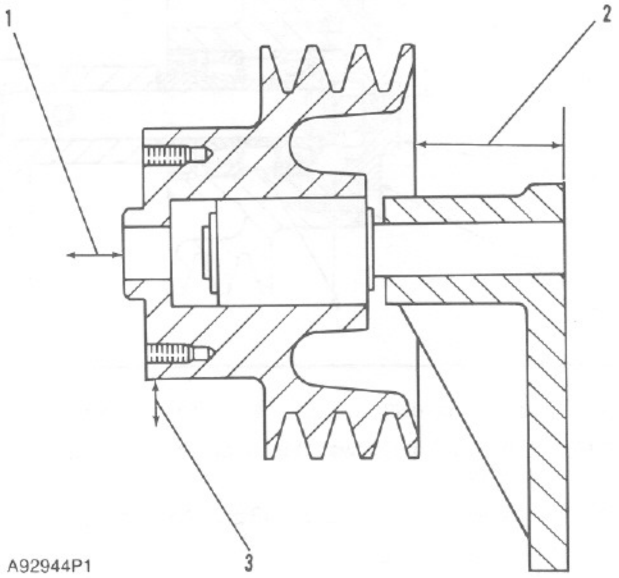
When a front power take off is used, increase torque for bolt to .... 950 ± 50 N•m (700 ± 37 lb ft)

(2) Distance from end of damper assembly to edge of dust shield .... 31.8 ± 1.5 mm (1.25 ± .06 in)

(3) When front power take off is used, tighten bolts to .... 55 ± 7 N•m (40 ± 5 lb ft)

Fan Mounting Pulley Assemblies

9L7243 Pulley Assembly



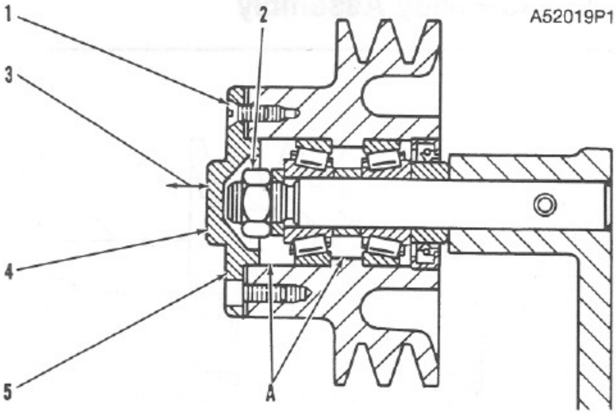
A92944P1

(1) End play of pulley .... 0.03 to 0.23 mm (.001 to .009 in)

(2) Dimension from mounting face of bracket to the rear face of pulley .... 53.1 mm (2.09 in)

(3) Maximum radial play of pulley .... 0.13 mm (.005 in)

6N7691 Pulley Assembly (with hexagon nut and pinned shaft).



(1) Torque for screws .... 4.5 ± 0.8 N•m (40 ± 7 lb in)

NOTE: The head of screws (1) must be below outer surface (5) of cover (4).

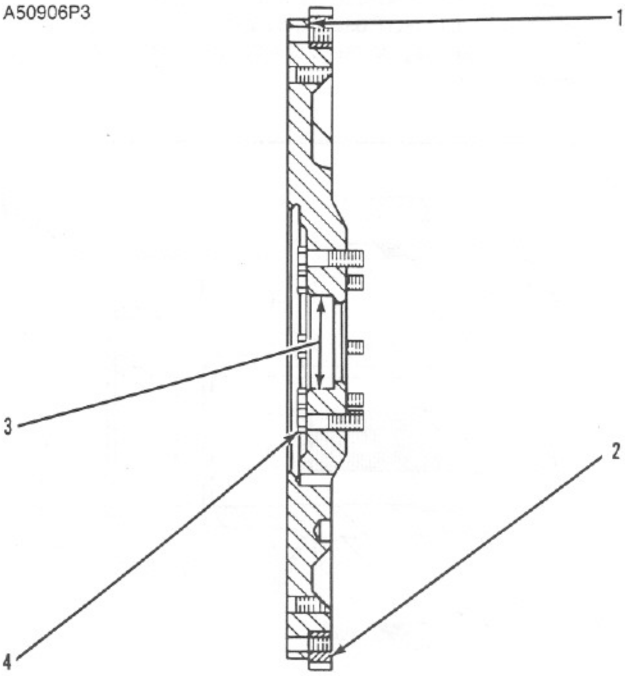
(2) Torque for nut .... 149 ± 20 N•m (110 ± 15 lb ft)

(3) *End play for the pulley .... 0.03 to 0.25 mm (.001 to .010 in)

NOTE: Put 2S3230 Bearing Lubricant in areas (A) until they are one-third to one-half full of lubricant.

*See 3208 Diesel Truck Engine Testing & Adjusting for end play adjustment procedure.

Flywheel



(1) Flywheel shoulder.

(2) Install ring gear so that Part No. is on this side. Ring gear must be assembled against shoulder of flywheel.

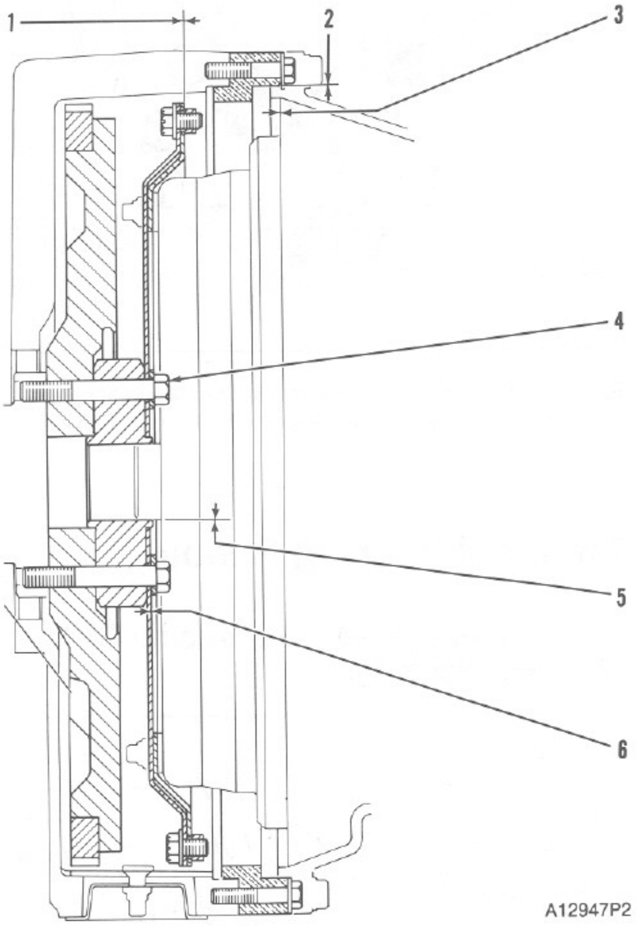
NOTE: Do not heat ring gear to more than 204°C (400°F) before installing on flywheel.

(3) Pilot bore.

(4) Torque for bolts that hold flywheel to crankshaft .... 90 ± 7 N•m (66 ± 5 lb ft) Put 5P3413 Sealant on bolt threads.

NOTE: Dash mark on flywheel must be in alignment with dash mark on crankshaft.

Mounting Group For AT540, MT643, and MT653 Allison Transmission



A12947P2

(1) Maximum face runout of flexplate measured at bolt circle diameter .... 0.76 mm (.030 in)

(2) Bore runout of spacer T.I.R.
(Total indicator reading)
AT540 .... 0.51 mm (.020 in)
MT643, MT653 .... 0.20 mm (.008 in)

(3) Face runout of spacer T.I.R.
(Total indicator reading)
AT540 .... 0.51 mm (.020 in)
MT643, MT653 .... 0.20 mm (.008 in)

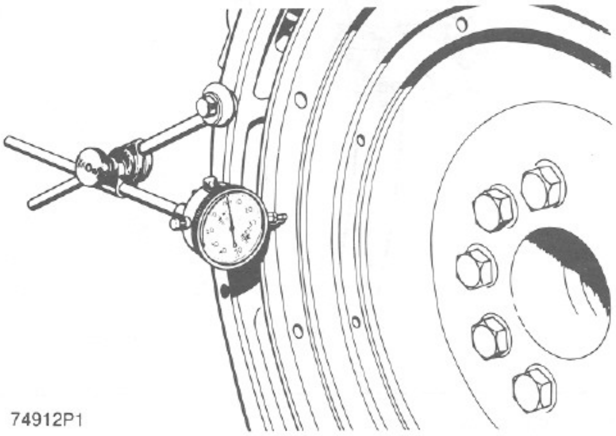
(4) Torque for bolts that hold flywheel and adapter to crankshaft .... 75 ± 7 N•m (55 ± 5 lb ft)

(5) Bore runout of adapter T.I.R.
(Total indicator reading)
AT540 .... 0.25 mm (.010 in)
MT643, MT653 .... 0.13 mm (.005 in)

(6) Face runout of adapter with flexplate installed [measured 76.2 mm (3.00 in) from center of bore] (Total indicator reading) .... 0.08 mm (.003 in)

Flywheel Runout

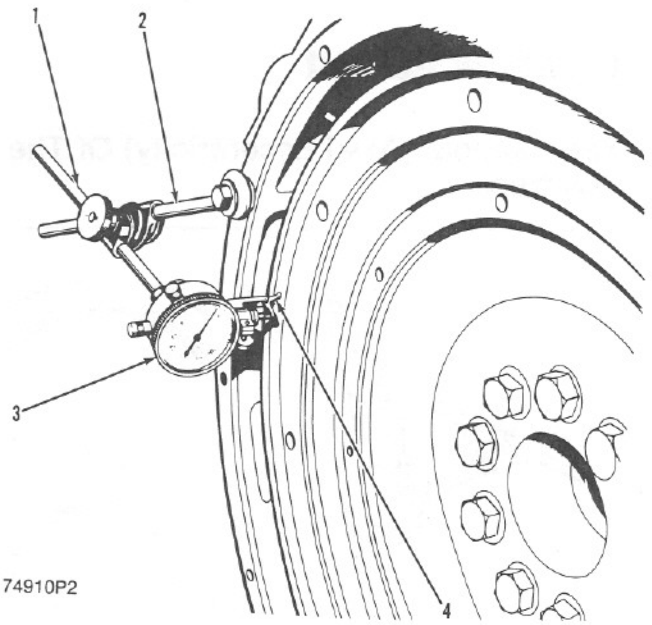
Face Runout (Axial Eccentricity) Of The Flywheel:



Checking Face Runout Of The Flywheel

1. Install the dial indicator as shown. Put a force on the flywheel toward the rear.
2. Set the dial indicator to read 0.00 mm (.000 in).
3. Turn the flywheel and read the indicator every 90°. Put a force on the flywheel to the rear before each reading.
4. The difference between the lower and higher measurements taken at all four points must not be more than 0.15 mm (.006 in), which is the maximum permissible face runout (axial eccentricity) of the flywheel.

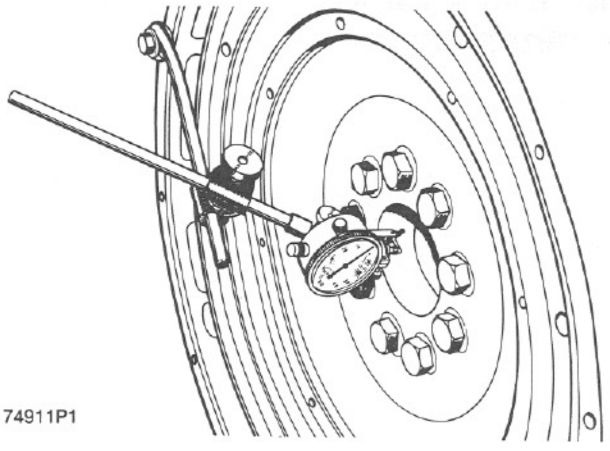
Bore Runout (Radial Eccentricity) Of The Flywheel:



74910P2

Checking Flywheel Bore

1. Install the dial indicator (3) and make an adjustment of the universal attachment (4) so it makes contact as shown.
2. Set the dial indicator to read 0.00 mm (.000 in).
3. Turn the flywheel and read the indicator every 90°.
4. The difference between the lower and higher measurements taken at all four points must not be more than 0.15 mm (.006 in), which is the maximum permissible bore runout (radial eccentricity) of the flywheel.

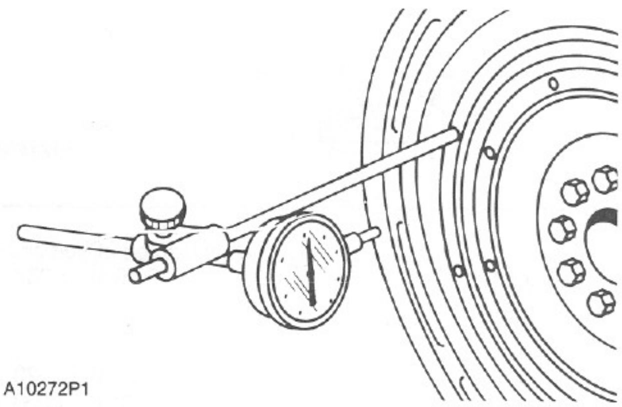


74911P1

5. Runout (eccentricity) of the bore for the pilot bearing for the flywheel clutch, must not exceed 0.13 mm (.005 in).

Flywheel Housing Runout

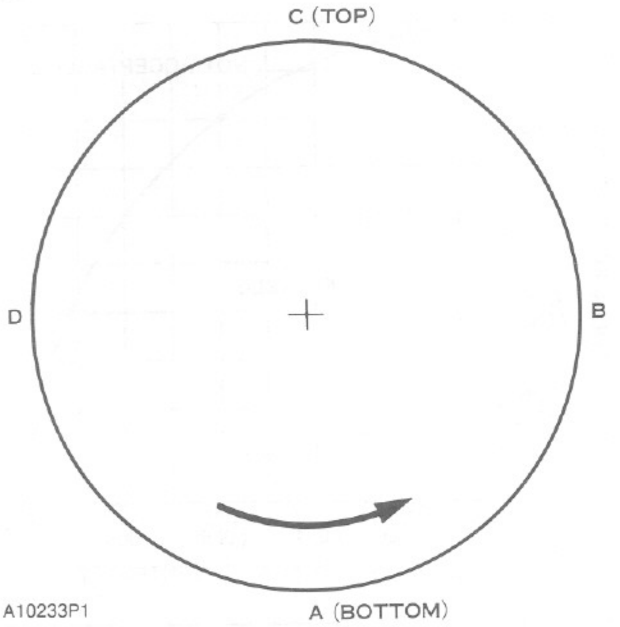
Face Runout (Axial Eccentricity) Of The Flywheel Housing:



A10272P1

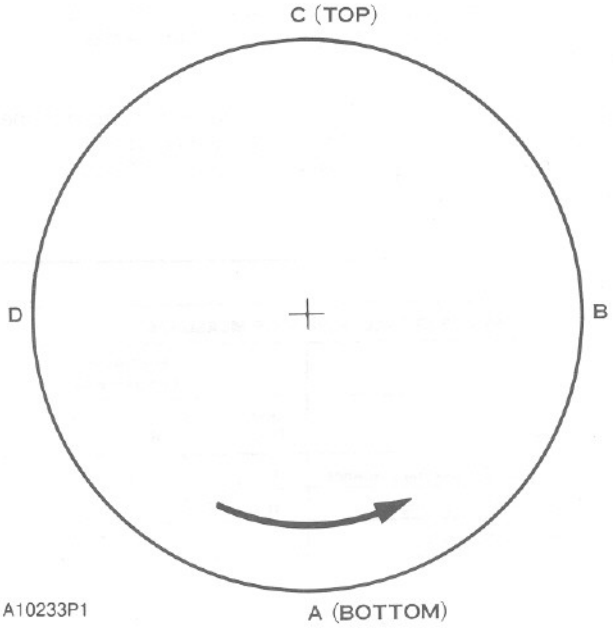
8T5096 Dial Indicator Group Installed

1. Fasten a dial indicator to the crankshaft flange so the anvil of the indicator will touch the face of the flywheel housing.
2. Put a force on the crankshaft toward the rear before reading the indicator at each point.

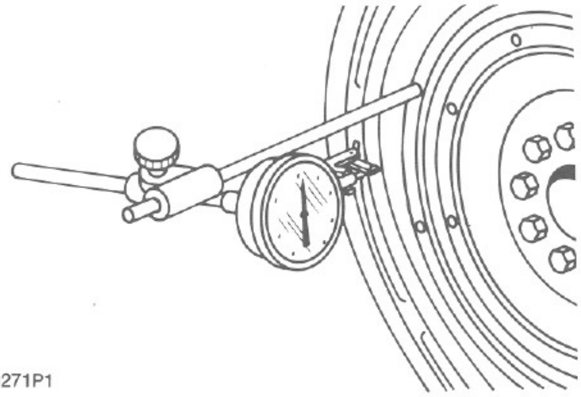


3. With dial indicator set at 0.00 mm (.000 in) at location (A), turn the crankshaft and read the indicator at locations (B), (C) and (D).
4. The difference between lower and higher measurements taken at all four points must not be more than 0.25 mm (.010 in), which is the maximum permissible face run out (axial eccentricity) of the flywheel housing.

Flywheel Housing Bore



NOTE: Write the dial indicator measurements with their positive (+) and negative (−) notation (signs). This notation is necessary for making the calculations in the chart correctly.



1. With the dial indicator in position at (C), adjust the dial indicator to "0" (zero). Push the crankshaft up against the top bearing. Write the measurement for bearing clearance on line 1 in column (C).
2. Divide the measurement from Step 1 by 2. Write this number on line 1 in columns (B) & (D).
3. Turn the crankshaft to put the dial indicator at (A). Adjust the dial indicator to "0" (zero).

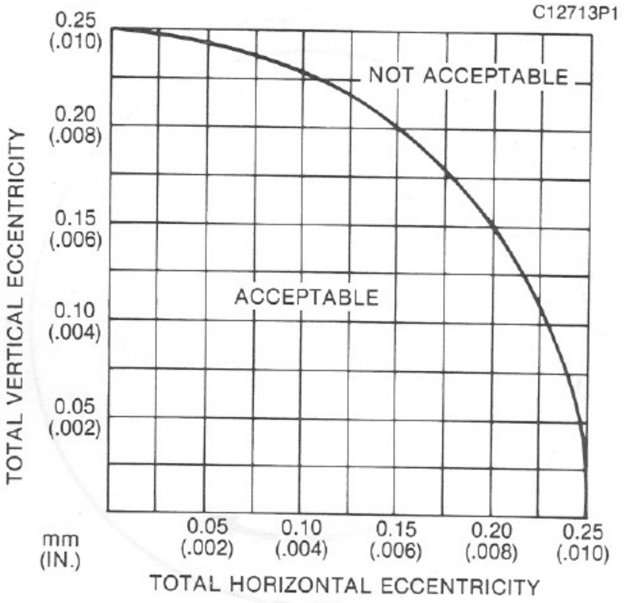
4. Turn the crankshaft counterclockwise to put the dial indicator at (B). Write the measurement in the chart.
5. Turn the crankshaft counterclockwise to put the dial indicator at (C). Write the measurement in the chart.
6. Turn the crankshaft counterclockwise to put the dial indicator at (D). Write the measurement in the chart.
7. Add lines I and II by columns.
8. Subtract the smaller number from the larger number in line III in columns (B) & (D). The result is the horizontal "eccentricity" (out of round). Line III, column (C) is the vertical eccentricity.

CHART FOR DIAL INDICATOR MEASUREMENTS

		Position of dial indicator			
	Line No.	A	B	C	D
Correction for bearing clearance	I	0			
Dial Indicator Reading	II	0			
Total of Line 1 & 2	III	0	**	*	**

*Total Vertical eccentricity (out of round).
**Subtract the smaller No. from the larger No. The difference is the total horizontal eccentricity.

A10234P1

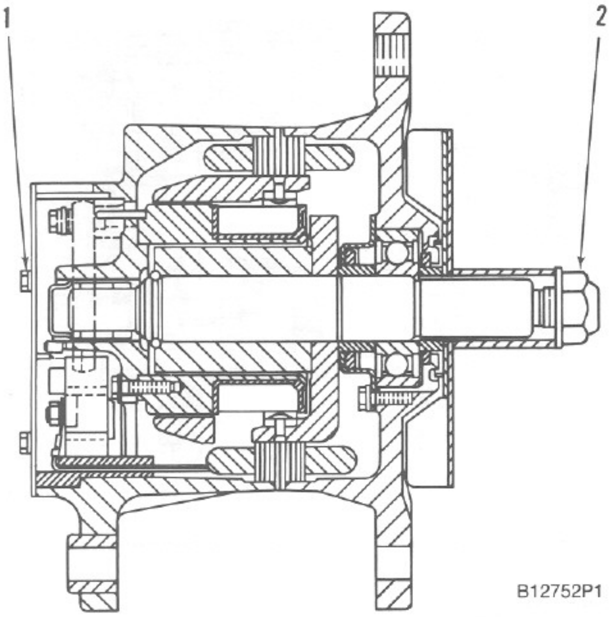


Total Horizontal Eccentricity

9. On the graph for total eccentricity find the point of intersection of the lines for vertical eccentricity and horizontal eccentricity.
10. If the point of intersection is in the range marked "Acceptable" the bore is in alignment. If the point of intersection is in the range marked "Not Acceptable", the flywheel housing must be changed.

Alternators And Regulators

Delco Remy Alternators



B12752P1

7G7889 Alternator

Voltage rating	12V
Polarity	Neg Grnd
Rotation	Either Direction
Speed for testing (rpm)	2600 to 6500
Output (cold)	28 A @ 14V
Output (cold)	62A @ 14V
Rated output (hot) at max speed	60 A
Field current at rated voltage and 27° C (80°F)	7 to 8A
Positive output terminal torque	6.2 to 8.0 N•m (55 to 71 lb in)
(1) Ground terminal torque	1.7 to 2.9 N•m (15 to 26 lb in)
(2) Shaft nut torque	95 to 109 N•m (70 to 80 lb ft)

Regulator (9G5235-Inside Alternator)

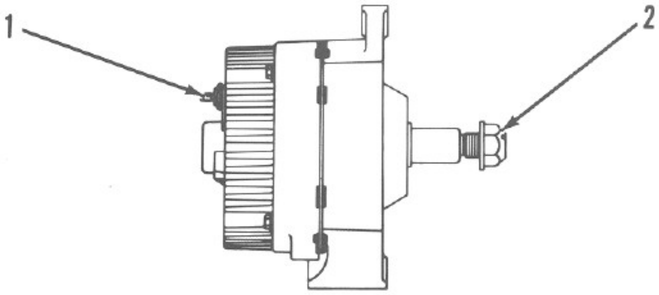
Voltage setting	No Adjustment
Permissible voltage range	13 to 15V

3T6352 Alternator

Voltage rating	24V
Polarity	Neg Grnd
Rotation	Either Direction
Speed for testing (rpm)	2600 to 6500
Output (cold)	15A @ 28V
Output (cold)	35A @ 28V
Rated output (hot) at max speed	35A
Field current at rated voltage and 27°C (80°F)	2.5 to 3.2A
Positive output terminal torque	6.2 to 8.0 N•m (55 to 71 lb in)
(1) Ground terminal torque	1.7 to 2.9 N•m (15 to 26 lb in)
(2) Shaft nut torque	95 to 109 N•m (70 to 80 lb ft)

Regulator (3T6354 - Inside alternator)

Voltage setting	No Adjustment
Permissible voltage range	26 to 30 V



A08440P3

9G6079 & 6T1194 Alternators

Voltage rating	12V
Polarity	Neg Grnd
Rotation	Either Direction
Output at 2000 rpm (cold)	30A
Output at 5000 rpm (cold)	57A
Rated output (hot)	61A
(1) Torque for stud nut for battery connection	2.8 to 4.5 N•m (25 to 40 lb in)
(2) Torque for pulley nut	100 ± 7 N•m (75 ± 5 lb ft)

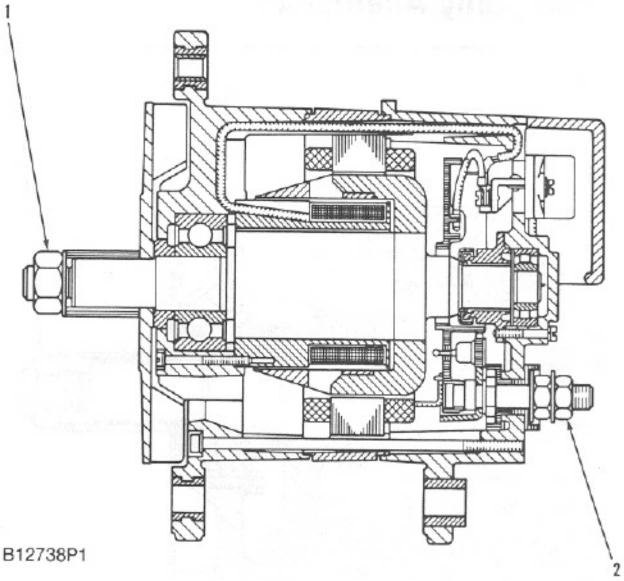
Voltage Regulator (3S8828) is internally mounted and is not adjustable.

9G6081 & 6T1196 Alternators

Polarity	Neg Grnd
Rotation	Either Direction
Output at 2600 rpm (cold)	25A
Output at 7000 rpm (cold)	41A
Rated output (hot)	40A
(1) Torque for stud nut for battery connection	2.8 to 4.5 N•m (25 to 40 lb in)
(2) Torque for pulley nut	100 ± 7 N•m (75 ± 5 lb ft)

Voltage Regulator (3T6354) is internally mounted and not adjustable.

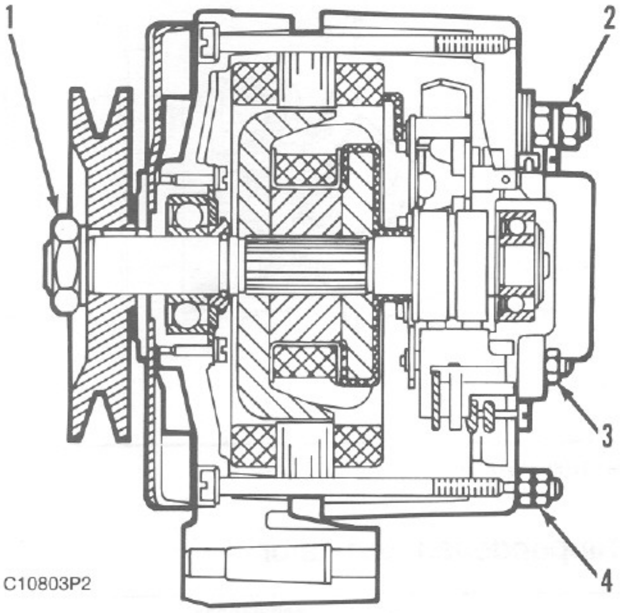
Bosch Alternators



B12738P1

7N9720 Alternator

Voltage rating	24V
Polarity	Neg Grnd
Rotation	Either Direction
Speed for testing (rpm)	4000
Output (cold)	47A
Output (hot)	37A
Field Current at 28V and 25° C (77°F)	1.8A
(1) Torque for pulley nut	95 to 110 N•m (70 to 80 lb ft)
(2) Torque for output terminal B+	7.5 to 10 N•m (5.5 to 7.0 lb ft)
Torque for ground terminal	2.1 to 2.8 N•m (19 to 25 in lb)
Regulator Number	9G7567

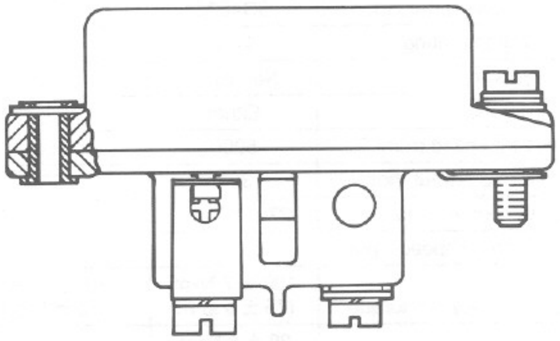


C10803P2

9W3043 Alternator

Voltage rating	24V
Polarity	Neg Grnd
Rotation	Clockwise
Speed for testing (rpm)	5000
Output (cold)	40A
Output (hot)	52A
Field current at 28V and 25°C (77°F)	2.9A
(1) Torque for pulley nut	50 ± 5 N•m (37 ± 4 lb ft)
(2) Torque for output terminal B+	7.8 ± 0.8 N•m (70 ± 7 lb in)
(3) Torque for field D+ terminal nut	1.70 ± 0.25 N•m (15 ± 2 lb in)
(4) Torque for ground (B-) terminal nut	3.60 ± 0.8 N•m (32 ± 7 lb in)
Torque for W terminal (not shown)	2.25 ± 0.25 N•m (20 ± 2 lb in)
Regulator Number	8C6145

Bosch Regulators



B12749P1

9G7567 Regulator

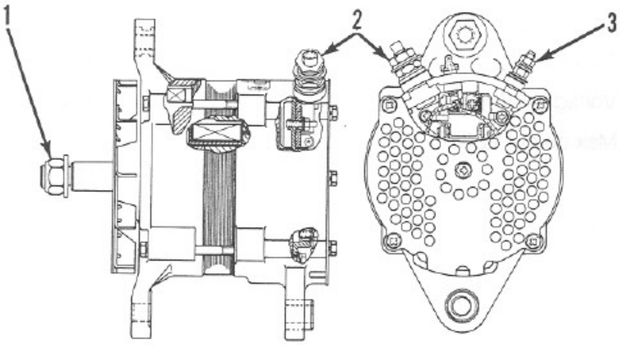
Voltage rating	28V
Polarity	Neg Grnd
Voltage setting range	26.7 to 28.3 V
Max output at 28V	40A

8C6145 Regulator

Voltage rating	28V
Polarity	Neg Grnd
Voltage setting range	27.5 to 28.5V
Max output at 28V	52A

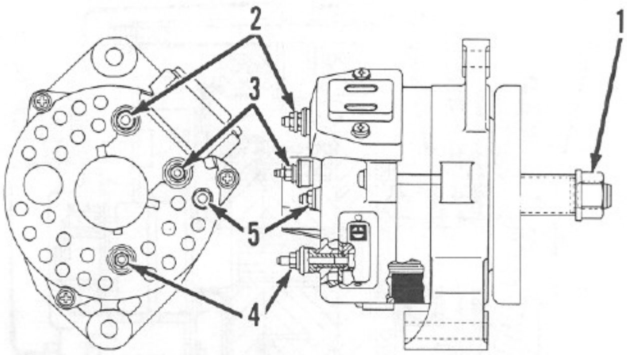
Nippondenso Alternator

Alternator Specifications		
Caterpillar No.	9G4574	8T9700
Voltage rating	24V	12V
Polarity	Neg Grnd	Neg Grnd
Rotation	Either	Clockwise
Test speed (rpm)	5000	5000
Rated output (hot)	35A	55A
Output voltage	27.5 ± 1.0V	14.25 ± .35V
Turn on speed (rpm)	2000	2000
(1) Pulley nut torque	100 ± 7 N•m (75 ± 5 lb ft)	100 ± 7 N•m (75 ± 5 lb ft)
(2) B+ nut torque	29 ± 8 N•m (21 ± 6 lb ft)	
(3) B− nut torque	4 ± 1 N•m (35 ± 9 lb in)	
(2) Battery terminal (B) torque		4.25 ± 0.85 N•m (38 ± 6 lb in)
(3) Ignition terminal (IG) torque		4.1 ± 1.0 N•m (36 ± 9 lb in)
(4) (R) terminal		4.1 ± 1.0 N•m (36 ± 9 lb in)
(5) Ground terminal (E)		4.25 ± 0.85 N•m (38 ± 6 lb in)



C10825P2

9G4574 Alternator

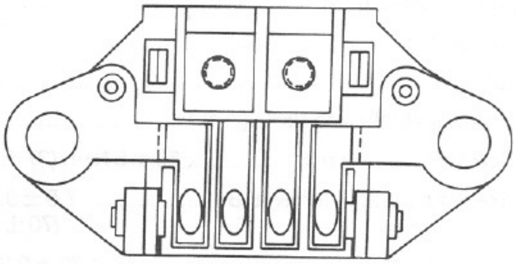


C12708P1

8T9700 Alternator

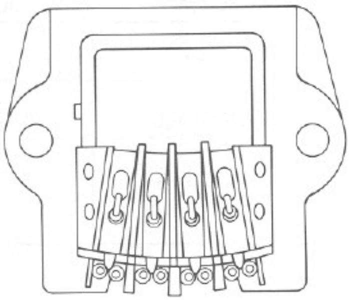
Nippondenso Regulator

Regulator Specifications		
Caterpillar No	7T2798	8T9693
Voltage rating	24V	12V
Polarity	Neg Grnd	Neg Grnd
Voltage range	27.5 ± 1V	14.25 ± .35V



C10874P1

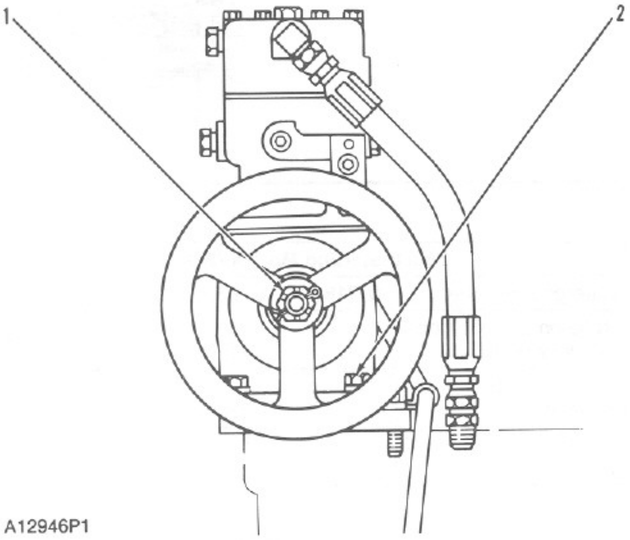
7T2798 Regulator



C12707P1

8T9693 Regulator

Air Compressor



A12946P1

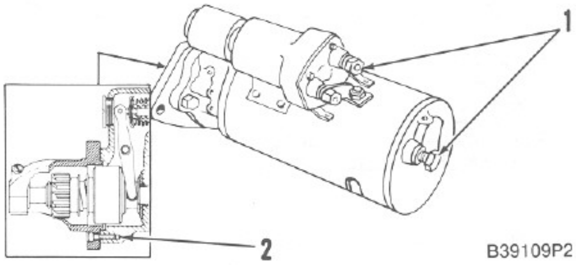
(1) Torque for nut that holds the drive pulley .... 70 N•m (50 lb ft)

NOTE: Tighten nut more to get alignment of hole for cotter pin.

(2) Torque for studs that hold the air compressor .... 70 ± 7 N•m (70 ± 5 lb ft)

Starter Motors

Delco Remy



B39109P2

Delco-Remy Starter Motors					
Voltage	12V	12V	24V	24V	24V
Caterpillar No.	4N8253	8C3643	2S0900	8C3647	8C3651
Rotation as seen from the drive end	CW	CW	CW	CW	CW
No Load Speed Min-Max rpm	4000-7000	5500-7800	5500-9000	6300-8400	6300-8400
Current Consumption (Draw) with solenoid at V*	140 to 215A	100 to 170A	70 to 110A	60 to 75A	60 to 75A

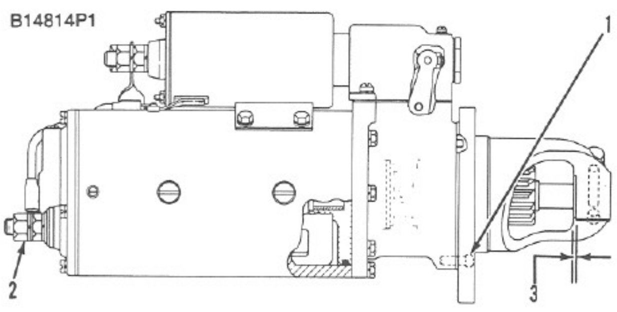
* 12V Starter Motors Solenoid at 10V
24V Starter Motors Solenoid at 20V

(1) Terminal nut torque .... 27.0 to 33.8 N•m (20 to 25 lb ft)

(2) Screw torque .... 17.6 to 23.0 N•m (13 to 17 lb ft)

Clearance between pinion and housing .... 8.3 to 9.9 mm (.33 to .39 in)

Prestolite



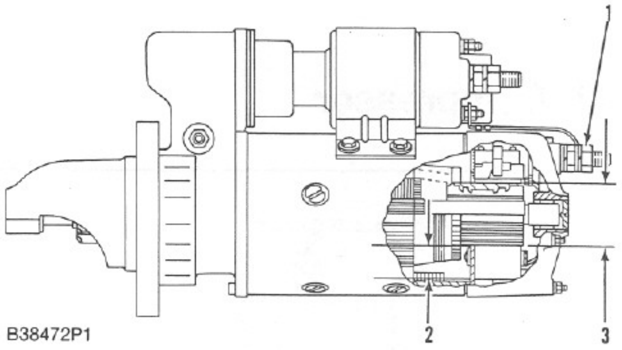
Prestolite Starting Motor (24V)	
Caterpillar Number	9G4337
Rotation as seen from the drive end	CW
No Load Speed Minimum rpm	5000
Current Consumption (Draw) at 20V	65A

(1) Housing bolt torque .... 11 N•m (8 lb ft)

(2) Terminal nut torque .... 27.0 to 33.8 N•m (20 to 25 lb ft)

(3) Clearance between pinion and housing .... 0.51 to 1.27 mm (.020 to .050 in)

Bosch



Bosch Starting Motors (24)			
Caterpillar Number	4N3181	3T6305	7T0798
Rotation as seen from the drive end	CW		
No Load Speed Minimum rpm	5500		
Minimum Current Draw	140A		

(1) Terminal nut torque .... 27 to 33 N•m (1.1 to 1.3 lb ft)

(2) Service limit of brushes .... 17.5 mm (.69 in)

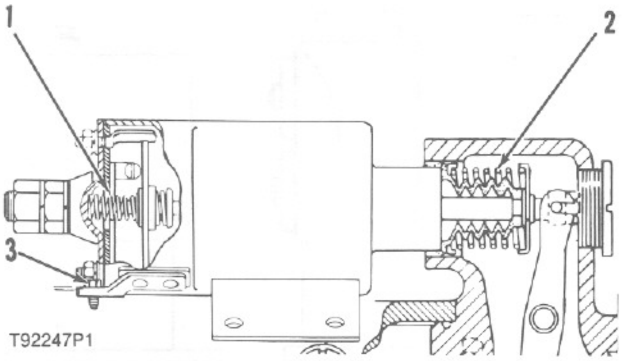
(3) Service limit of commutator diameter .... 48 mm (1.9 in)

Pinion to ring gear clearance .... 1.5 to 5.5 mm (.06 to .22 in)

Solenoid terminal torque .... 4 to 5 mm (.16 to .20 in)

Starter Motor Solenoids

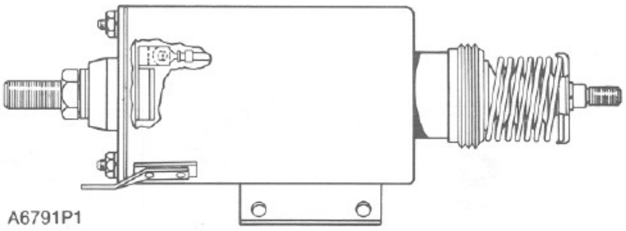
Delco-Remy



T92247P1

Voltage	24V
Caterpillar Part Number	7T8854
Current Consumption (Draw):	
Pull-in windings	9 to 11.5A @ 5V
Hold-in windings	6.8 A max. @ 20V
Voltage	12V
Caterpillar Part Number	7T0258
Caterpillar Part Number	8T8822
Current Consumption (Draw):	
Pull-in windings	28 to 35.7A @ 5V
Hold-in windings	13 to 15.4A @ 10V
(1) 4M1815 Spring (contact release):	
Length under test force	10.7 mm (.42 in)
Test force	40 ± 2 N (9.0 ± .5 lb)
Free length after test	21.1 ± 0.5 mm (.83 ± .02 in)
Outside diameter	9.53 ± 0.25 mm (.375 ± .010 in)
(2) 9M7609 Spring (to return the clutch lever):	
Length under test force	39.6 mm (1.56 in)
Test force	62 ± 2 N (14.0 ± .5 lb)
Free length after test	70.9 ± 0.5 mm (2.79 ± .02 in)
Outside diameter	35.38 ± 0.35 mm (1.393 ± .015 in)
(3) Torque for small terminal nuts	1.8 to 3.4 N•m (16 to 30 lb in)
Torque for large terminal nuts	27.1 to 33.7 N•m (20 to 25 lb ft)

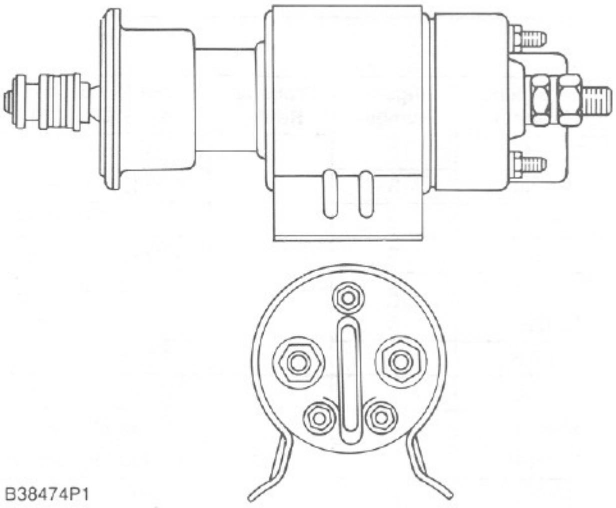
Prestolite



A6791P1

Voltage	24V
Caterpillar Part Number	3T8635
Current Consumption (Draw):	
Pull-in windings	23.2 to 26.6A @ 12V
Hold-in windings	4.1 to 4.8A @ 12V
Torque for small terminals	1.7 to 2.2 N (15 to 20 lb in)

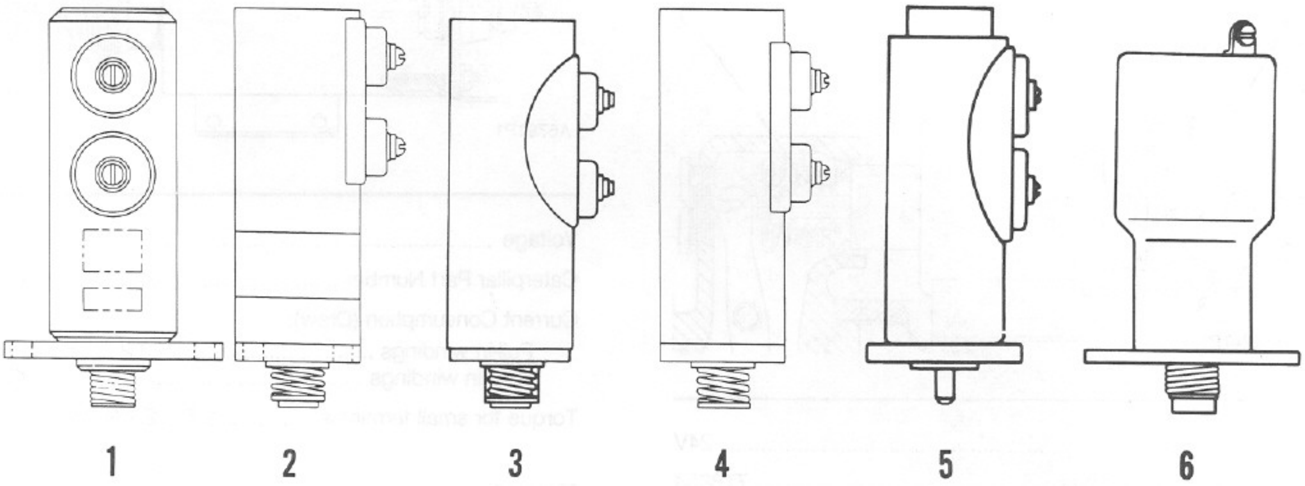
Bosch



B38474P1

Voltage	24V
Caterpillar Part Number	3T0868
Current Consumption (Draw):	
Pull-in windings	8.3 to 12.5A at 5V
Hold-in windings	5.4 to 6.5A at 20V
Resistance of pull-in windings	.4 to .6 ohm
Resistance of hold-in windings	3.1 to 3.7 ohm

Shutoff Solenoids



C12710P1

Caterpillar Number	Figure Number	Voltage Rating	Coil Resistance at 25°C (77°F)
6N3749	1	12V	4.23 to 5.17 ohms
6T4750	3		4.23 to 5.17 ohms
6T6121	2		4.23 to 5.17 ohms
7N8883	3		4.23 to 5.17 ohms
8C5523	5		1.26 to 1.40 ohms
9G3227	5		1.26 to 1.40 ohms
9N1068	6		4.3 to 5.3 ohms
6T4126	4	24V	17.7 to 21.7 ohms
6T6122	2		17.7 to 21.7 ohms
7N8884	1		15.3 to 18.7 ohms
7N8886	3		17.7 to 21.7 ohms
8C5524	5		4.86 to 5.38 ohms
9G3228	5		4.86 to 5.38 ohms

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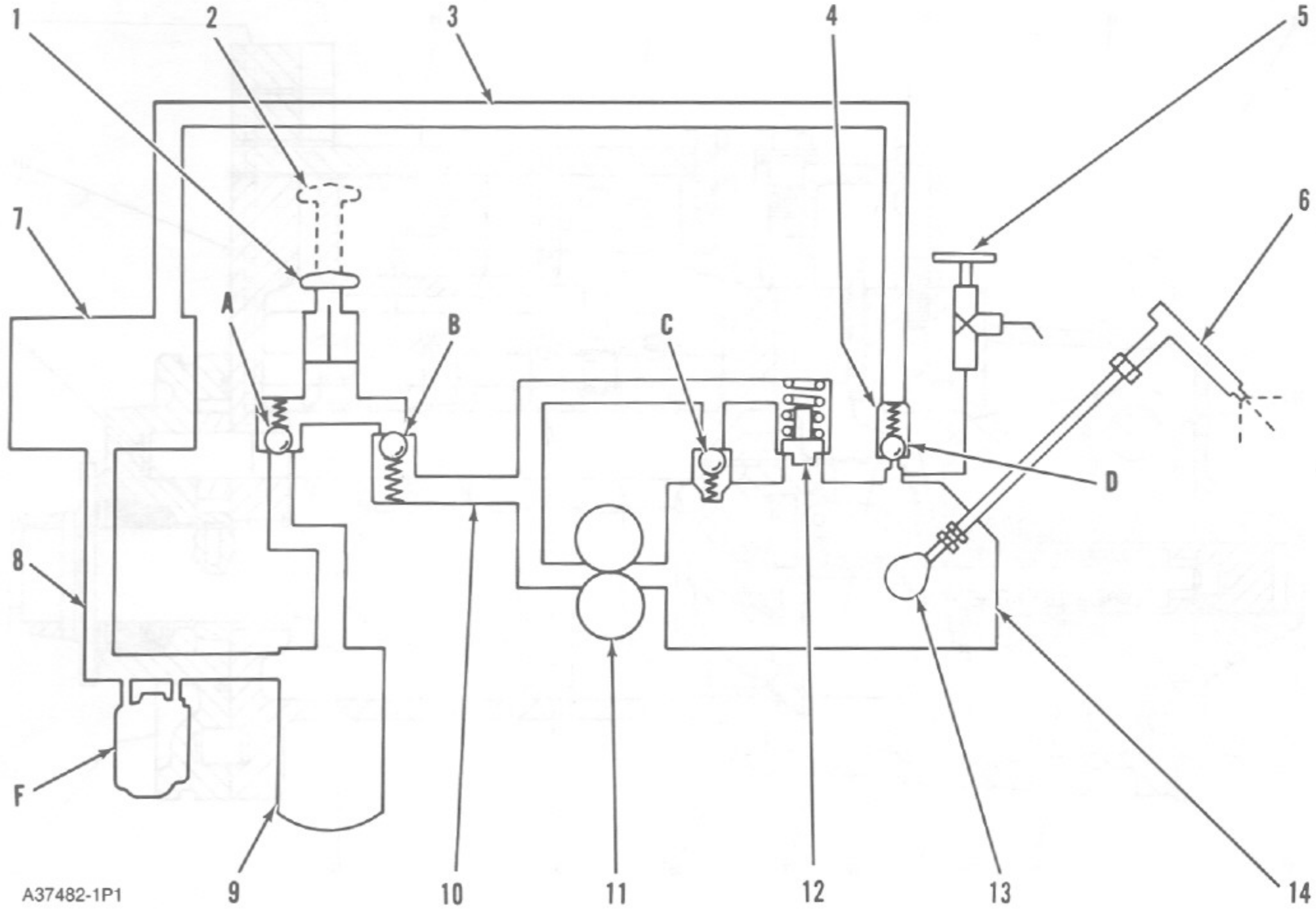
Systems Operation

Fuel System

The sleeve metering fuel system is a pressure type fuel system. The name for the fuel system is from the method used to control the amount of fuel sent to the cylinders. This fuel system has an injection pump for each cylinder of the engine. It also has a fuel transfer pump on the front of the injection pump housing. The governor is on the rear of the injection pump housing.

The drive gear for the fuel transfer pump is on the front of the camshaft for the injection pumps. The carrier for the governor weights is bolted to the rear of the camshaft for the injection pumps. The injection pump housing has a bearing at each end to support the camshaft. The camshaft for the sleeve metering fuel system is driven by the timing gears at the front of the engine.

The injection pumps, lifters and rollers, and the camshaft are all inside of the pump housing. The pump housing and the governor housing are full of fuel at transfer pump pressure (fuel system pressure).



Schematic Of Fuel System

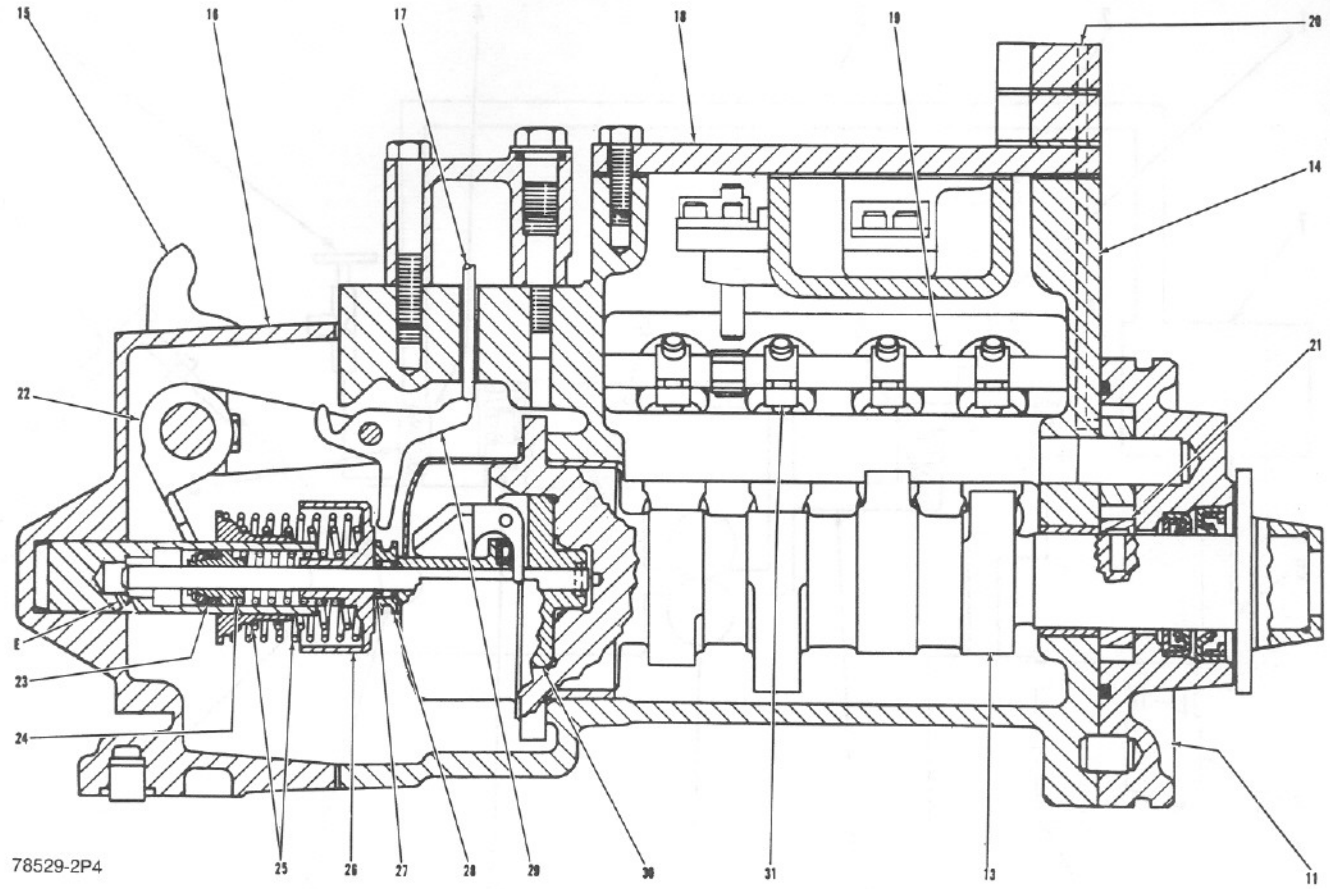
(1) Fuel priming pump (closed position). (2) Fuel priming pump (open position). (3) Return line for constant bleed valve. (4) Constant bleed valve. (5) Manual bleed valve. (6) Fuel injection nozzle. (7) Fuel tank. (8) Fuel inlet line. (9) Fuel filter. (10) Fuel line to injection pump. (11) Fuel transfer pump. (12) Fuel bypass valve. (13) Camshaft. (14) Housing for fuel injection pumps. (A) Check valve. (B) Check valve. (C) Check valve. (D) Check valve. (F) Water Separator.

NOTICE

Diesel fuel is the only lubrication for the moving parts in the transfer pump, injection pump housing and the governor. The injection pump housing must be full of fuel before turning the camshaft.

This fuel system has governor weights, a thrust collar and two governor springs. One governor spring is for high idle and the other governor spring is for low idle. Rotation of the shaft for governor control, compression of the governor springs, movement of connecting linkage in the governor and injection pump housing controls the amount of fuel sent to the engine cylinders.

Fuel from fuel tank (7) is pulled by fuel transfer pump (11) through water separator (F) (if so equipped) and fuel filter (9). From fuel filter (9) the fuel goes to housing for fuel injection pumps (14). The fuel goes in housing (14) at the top and goes through inside passage (20) to fuel transfer pump (11).



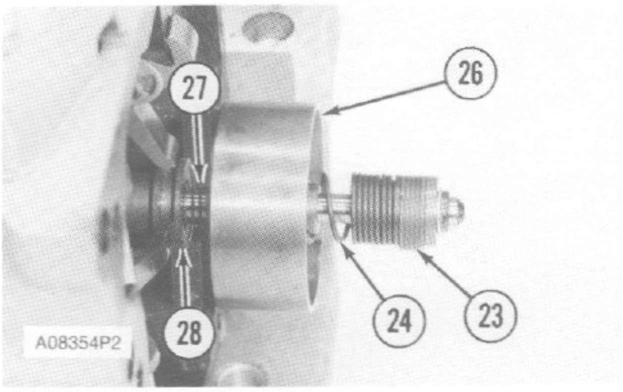
Cross Section Of Fuel System With Dashpot Governor
(11) Fuel transfer pump. (13) Camshaft. (14) Housing for fuel injection pumps. (15) Lever. (16) Governor housing. (17) Load stop pin. (18) Cover. (19) Sleeve control shafts (two). (20) Inside fuel passage. (21) Drive gear for fuel transfer pump. (22) Lever on governor shaft. (23) Piston for dashpot governor. (24) Spring for dashpot governor. (25) Governor springs (inner spring is for low idle: outer spring is for high idle). (26) Spring seat. (27) Over fueling spring. (28) Thrust collar. (29) Load stop lever. (30) Carrier and governor weights. (31) Sleeve levers. (E) Orifice for dashpot.

From fuel transfer pump (11), fuel under pressure, fills the housing for the fuel injection pumps (14). Pressure of the fuel in housing (14) is controlled by bypass valve (12). Pressure of the fuel at FULL LOAD is 205 ± 35 kPa (30 ± 5 psi). If the pressure of fuel in housing (14) gets too high, bypass valve (12) will move (open) to let some of the fuel return to the inlet of fuel transfer pump (11).

Lever (15) for the governor is connected by linkage and governor springs (25) to the sleeve control shafts (19). Any movement of lever (22) will cause a change in the position of sleeve control shafts (19).

When lever (15) is moved to give more fuel to the engine, lever (22) will put governor springs (25) in compression and move thrust collar (28) forward. As thrust collar (28) moves forward, the connecting linkage will cause sleeve control shafts (19) to turn. With this movement of the sleeve control shafts, levers (31) will lift sleeves (32) to make an increase in the amount of fuel sent to the engine cylinders.

When starting the engine, the force of over fueling spring (27) is enough to push thrust collar (28) to the full fuel position. This lets the engine have the maximum amount of fuel for injection when starting. At approximately 400 rpm, governor weights (30) make enough force to push spring (27) together. Thrust collar (28) and spring seat (26) come into contact. From this time on, the governor works to control the speed of the engine.



Governor Parts
(23) Piston for dashpot governor. (24) Spring for dashpot governor. (26) Spring seat. (27) Over fueling spring. (28) Thrust collar.

When governor springs (25) are put in compression, the spring seat at the front of the governor springs will make contact with load stop lever (29). Rotation of the load stop lever moves load stop pin (17) up until the load stop pin comes in contact with the stop bar or stop screw. This stops the movement of thrust collar (28), the connecting levers, and sleeve control shafts (19). At this position, the maximum amount of fuel per stroke is being injected by each injection pump.

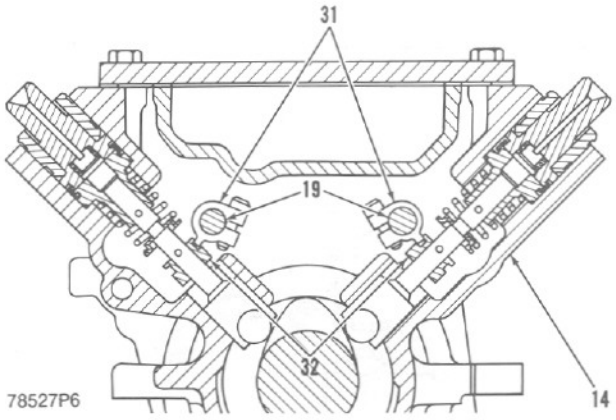
The carrier for governor weights (30) is held on the rear of camshaft (13) by bolts. When engine rpm goes up, injection pump camshaft (13) turns faster. Any change of camshaft rpm will change the rpm and position of governor weights (30). Any change of governor weight position will cause thrust collar (28) to move. As governor weights (30) turn faster, thrust collar (28) is pushed toward governor springs (25). When the force of governor springs (25) is balanced by the centrifugal force of the governor weights, sleeves (32) of the injection pumps are held at a specific position to send a specific amount of fuel to the engine cylinders.

The parts of the dashpot work together to make the rpm of the engine steady. The dashpot works as piston (23) moves in the cylinder which is filled with fuel. The movement of piston (23) in the cylinder either pulls fuel into the cylinder or pushes it out. In either direction the flow of fuel is through orifice (E). The restriction to the flow of fuel by orifice (E) gives the governor its function.

When the load on the engine decreases, the engine starts to run faster and governor weights (30) put force against springs (25). This added force puts more compression on springs (25) and starts to put spring (24) in compression. Spring (24) is in compression because the fuel in the cylinder behind piston (23) can only go out through orifice (E). The rate of flow through orifice (E) controls how fast piston (23) moves. As the fuel is pushed out of the cylinder by piston (23), the compression of spring (24) becomes gradually less.

When springs (25) and spring (24) are both in compression, their forces work together against the force of weights (30). This gives the effect of having a governor spring with a high spring rate. A governor spring with a high spring rate keeps the engine speed from having oscillations during load changes.

When the load on the engine increases, the engine starts to run slower. Governor weights (30) puts less force against spring (25). Spring (25) starts to push seat (26) to give more fuel to the engine. Seat (26) is connected to piston (23) by spring (24). When seat (26) starts to move, the action puts spring (24) in tension. As piston (23) starts to move, a vacuum is made inside the cylinder. The vacuum will pull fuel into the cylinder through orifice (E). The rate of fuel flow through orifice (E) again controls how fast piston (23) moves. During this condition, spring (24) is pulling against springs (25). This makes the movement of seat (26) and springs (25) more gradual. This again gives the effect of a governor spring with a high spring rate.



Fuel System Components
(14) Housing for fuel injection pumps. (19) Sleeve control shafts. (31) Sleeve levers. (32) Sleeves.

When the governor control lever is turned toward the FUEL-OFF position with the engine running, there is a reduction of force on governor springs (25). The movement of the linkage in the governor will cause fuel control shafts (19) to move sleeves (32) down, and less fuel will be injected in the engine cylinders.

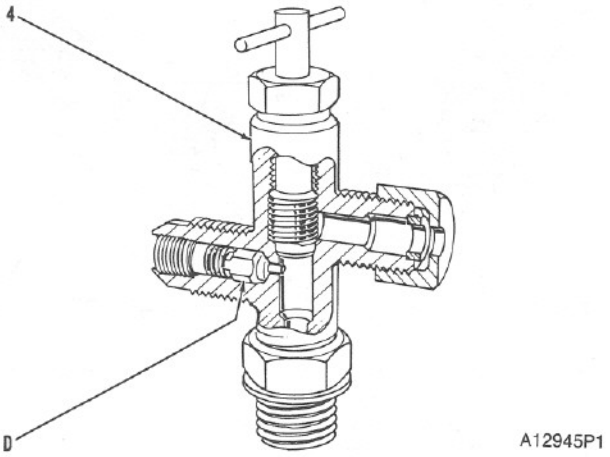
To stop the engine, turn the ignition switch to the "OFF" position. This will cause the shut-off solenoid to move linkage in the fuel pump housing. Movement of the linkage will cause sleeve levers (31) to move sleeves (32) down, and no fuel is sent to the engine cylinders. With no fuel going to the engine cylinders, the engine will stop.

Flow Of Fuel Using The Priming Pump

When the handle of priming pump (2) is pulled out, negative air pressure in priming pump (2) opens check valve (A) and pulls fuel from fuel tank (7). Pushing the handle in closes check valve (A) and opens check valve (B). This pushes air and/or fuel into housing (14) through the fuel passages and check valve (C). More operation of priming pump (2) will pull fuel from fuel tank (7) until the fuel lines, fuel filter (9) and housing (14) are full of fuel. Do this until the flow of fuel from manual bleed valve (5) is free of air bubbles.

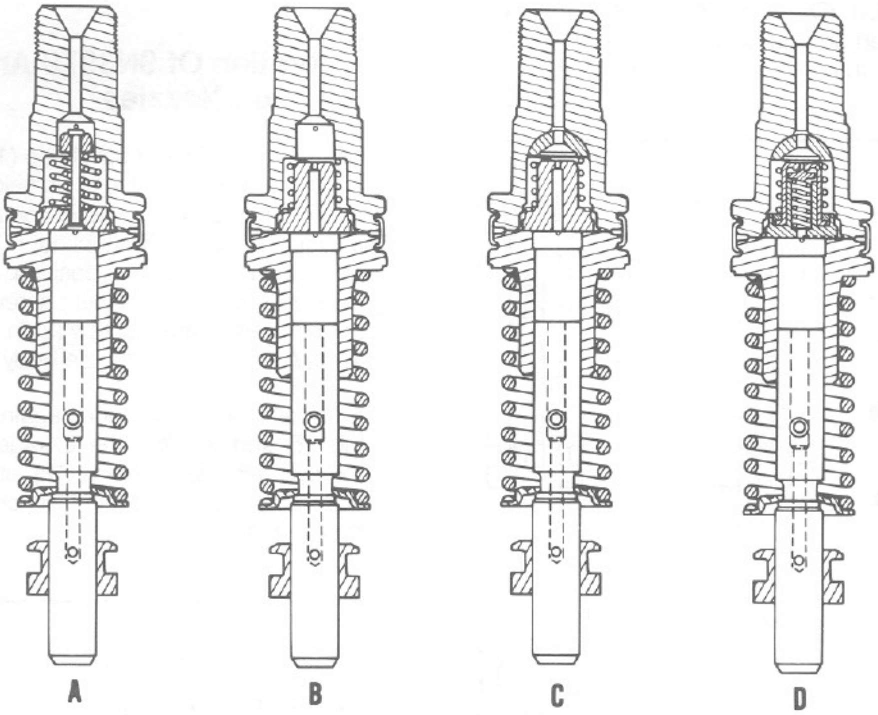
Constant Bleed Valve

Constant bleed valve (4) lets approximately 9 gallons of fuel per hour go back to fuel tank (7). This fuel goes back to fuel tank (7) through return line for constant bleed valve (3). This flow of fuel removes air from housing (14) and also helps to cool the fuel injection pump. Check valve (D) makes a restriction in this flow of fuel until the pressure in housing (14) is at 55 ± 20 kPa (8 ± 3 psi).



Constant Bleed Valve
(4) Constant bleed valve. (D) Check valve.

Fuel Injection Pumps



A. 9N5857 Fuel Injection Pump uses a reverse flow check valve (RFC) and is used in engines with serial nos. 2Z1 to 2Z13749.

B. 4W5868 Fuel Injection Pump uses an orificed delivery valve (ODV) and is used in engines with serial nos. 2Z13750 to 2Z34220.

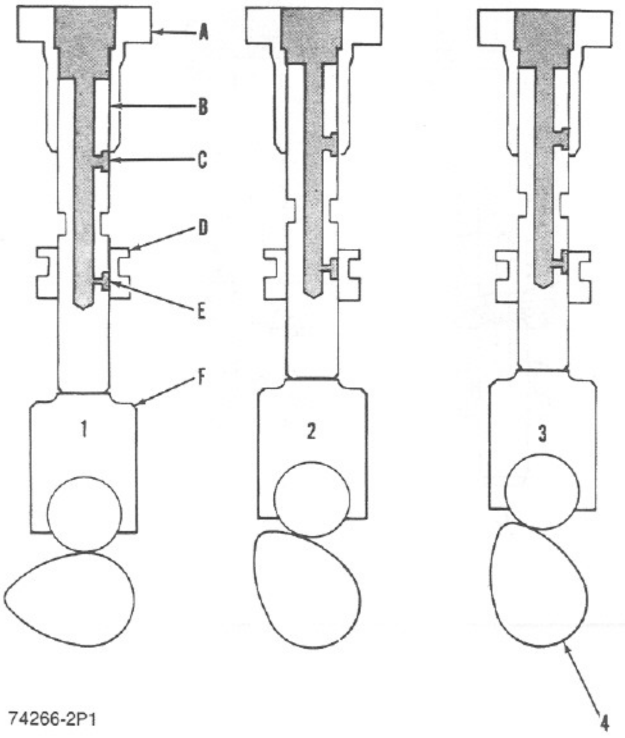
C. 7W8040 Fuel Injection Pump also has an orificed delivery valve (ODV). This fuel injection pump is used in engines with serial nos. 2Z24754 to 2Z34220*.

D. 7C8927 Fuel Injection Pump uses an orificed reverse flow check. Valve (ORFC) is used in engines with serial nos. 2Z34221-Up.

*The engines rated at 240 hp at 2200 rpm and the air to air aftercooled (ATAAC) engines above 250 hp that have 12.5° BTC timing use this fuel system.

Operation Of Fuel Injection Pumps

The main components of a fuel injection pump in the sleeve metering fuel system are barrel (A), plunger (B), and sleeve (D). Plunger (B) moves up and down inside barrel (A) and sleeve (D). Barrel (A) is stationary while sleeve (D) is moved up and down on plunger (B) to make a change in the amount of fuel for injection.



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Fuel Injection Sequence
(1), (2), (3) Injection stroke (positions) of a fuel injection pump. (4) Injection pump camshaft. (A) Barrel. (B) Plunger. (C) Fuel inlet. (D) Sleeve. (E) Fuel outlet. (F) Lifter.

When the engine is running, fuel under pressure from the fuel transfer pump goes in the center of plunger (B) through fuel inlet (C) during the down stroke of plunger (B). Fuel cannot go through fuel outlet (E) at this time because it is stopped by sleeve (D), (see position 1).

Fuel injection starts (see position 2) when plunger (B) is lifted up in barrel (A) enough to close fuel inlet (C). There is an increase in fuel pressure above plunger (B), when the plunger is lifted by camshaft (4). The fuel above plunger (B) is injected into the engine cylinder.

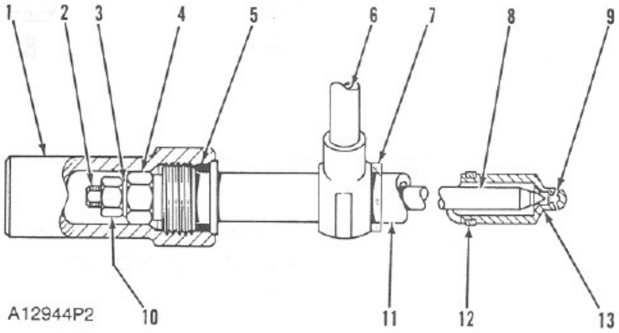
Injection will stop (see position 3) when fuel outlet (E) is lifted above the top edge of sleeve (D) by camshaft (4). This movement lets the fuel that is above, and in, plunger (B) go through fuel outlet (E) and return to the fuel injection pump housing.

When sleeve (D) is raised on plunger (B), fuel outlet (E) is covered for a longer time, causing more fuel to be injected in the engine cylinders. If sleeve (D) is low on plunger (B) fuel outlet (E) is covered for a shorter time, causing less fuel to be injected.

Operation Of 9N3979 And 1W5829 Fuel Injection Nozzles

The fuel inlet (6) and nozzle tip (13) are parts of the nozzle body (11). Valve (8) is held in position by spring force. Force of the spring is controlled by pressure adjustment screw (3). Locknut (4) holds pressure adjustment screw (3) in position. The lift of valve (4) is controlled by lift adjustment screw (2). Locknut (10) holds lift adjustment screw (2) in position. Compression seal (7) goes on the nozzle body (11).

Compression seal (7) goes against the fitting of fuel inlet (6) and prevents the leakage of compression from the cylinder. Carbon dam (12), at the lower end of the nozzle body (11), prevents the deposit of carbon in the bore in the cylinder head.



A12944P2

Fuel Injection Nozzle
(1) Cap. (2) Lift adjustment screw. (3) Pressure adjustment screw. (4) Locknut for pressure adjustment screw. (5) O-ring seal. (6) Fuel inlet. (7) Compression seal. (8) Valve. (9) Orifices (four). (10) Locknut for lift adjustment screw. (11) Nozzle body. (12) Carbon dam. (13) Nozzle tip.

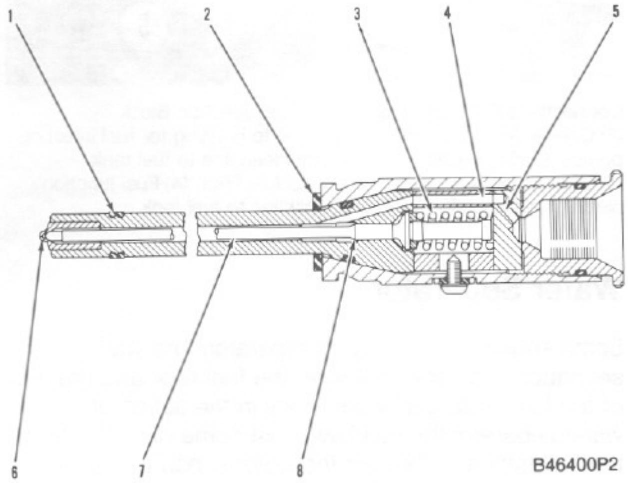
Fuel, under high pressure from the fuel injection pump goes through the hole in fuel inlet (6). The fuel then goes around valve (8), fills the inside of the nozzle body (11) and pushes against the valve guide. When the force made by the pressure of the fuel is more than the force of the spring, valve (8) will lift. When valve (8) lifts, fuel under high pressure will go through the four 0.325 mm (.0128 in) orifices (9) into the cylinder. When the fuel is sent to the cylinder, the force made by the pressure of the fuel in the nozzle body will become less. The force of the spring will then be more than the force of the pressure of the fuel in the nozzle body. Valve (8) will move to the closed position.

Valve (8) is a close fit with the inside of nozzle tip (13), this makes a positive seal for the valve.

When the fuel is sent to the cylinder, a very small quantity of fuel will leak by the valve guide. This fuel gives lubrication to the moving parts of the fuel injection nozzle.

Operation Of 7000 Series Fuel Injection Nozzle

The fuel injection nozzle goes through the cylinder head into the combustion chamber. The fuel injection pump sends fuel with high pressure to the fuel injection nozzle where the fuel is made into a fine spray for good combustion.



Fuel Injection Nozzle
(1) Carbon dam. (2) Seal. (3) Spring. (4) Passage. (5) Inlet passage. (6) Orifice. (7) Valve. (8) Diameter.

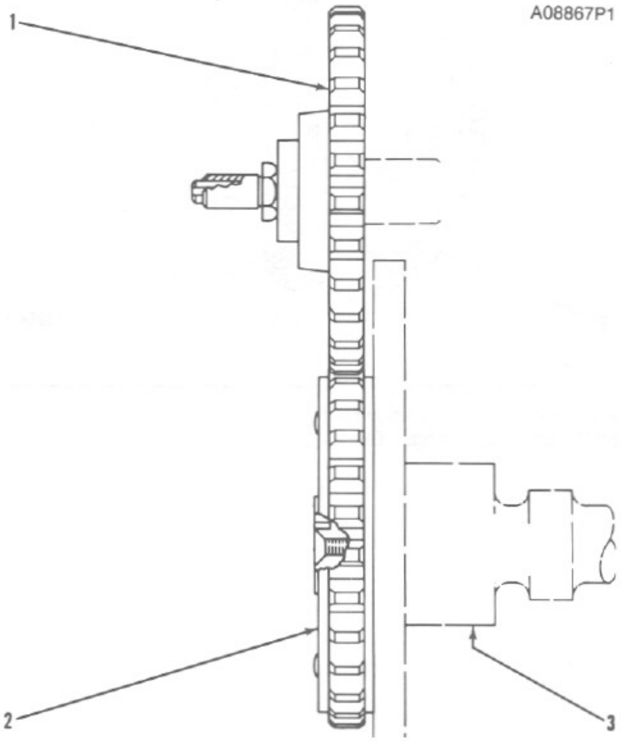
Seal (2) goes against the cylinder head and prevents leakage of compression from the cylinder. Carbon dam (1) keeps carbon out of the bore in the cylinder head for the nozzle.

Fuel with high pressure from the fuel injection pump goes into inlet passage (5). Fuel then goes into passage (4) to the area below diameter (8) of valve (7). When the pressure of the fuel that pushes against diameter (8) becomes greater than the force of spring (3), valve (7) lifts up. When valve (7) lifts, the tip of the valve comes off the nozzle seat and the fuel will go through the four 0.29 mm (.011 in) orifices (6) into the combustion chamber.

The injection of fuel continues until the pressure of fuel against diameter (8) becomes less than the force of spring (3). With less pressure against diameter (8), spring (3) pushes valve (7) against the nozzle seat and stops the flow of the fuel to the combustion chamber.

Automatic Timing Advance Unit

The automatic timing advance unit (2) is installed on the front of the camshaft (3) for the engine. The automatic timing advance unit (2) drives the gear (1) on the camshaft for the fuel injection pump. This gear is the drive for the camshaft for the fuel injection pump.

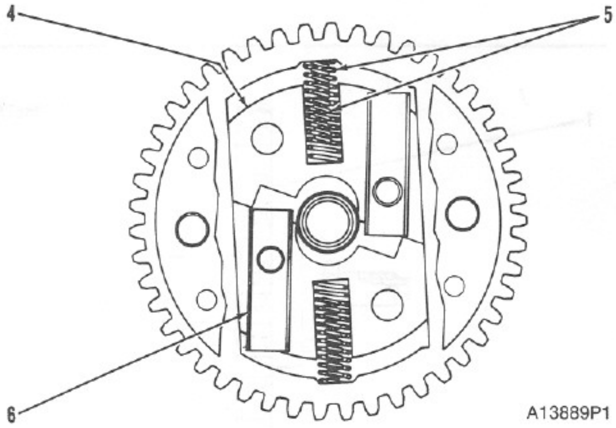


Automatic Timing Advance Unit
(1) Gear on camshaft for fuel injection pump. (2) Automatic timing advance unit. (3) Camshaft for the engine.

The weights (4) in the timing advance are driven by two slides (6) that fit into notches made on an angle in the weights. The slides (6) are driven by two dowels which are in the drive gear for the engine camshaft. As centrifugal force (rotation) moves weights (4) outward against the force of springs (5), the movement of the notches in weights (4) will cause the slides to make a change in the angle between the timing advance gear and the two drive dowels in the drive gear for the engine camshaft. Since the timing advance unit drives the gear (1) on the camshaft for the fuel injection pump, the fuel injection timing is also changed.

There are two different timing advance units used on the 3208 Truck Engine. One unit will give 5° of timing advance, and the other gives 3.5° of timing advance. The timing advance unit begins to advance the timing at low idle rpm and stops advance at rated engine rpm. No adjustment can be made to the automatic timing advance unit.

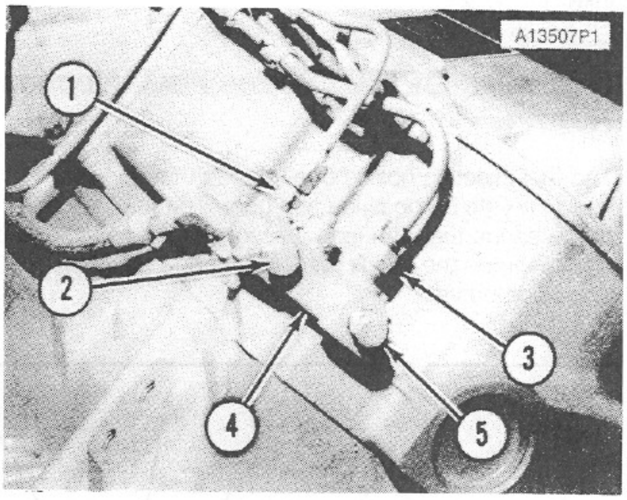
Lubrication oil for the timing advance unit comes from drilled holes that connect with the front bearing for the engine camshaft.



Automatic Timing Advance Unit
(4) Weights. (5) Springs. (6) Slides.

Fuel Junction Block

The location of the fuel junction block (4) is at the right rear of the engine. The fuel lines from the fuel tank and the engine connect at fuel junction block (4).



Connections For Fuel Lines At the Fuel Junction Block
(1) Connection for constant bleed line to housing for fuel injection pumps. (2) Connection for constant bleed line to fuel tank.
(3) Connection for fuel supply line to fuel filter. (4) Fuel junction block. (5) Connection for fuel supply line to fuel tank.

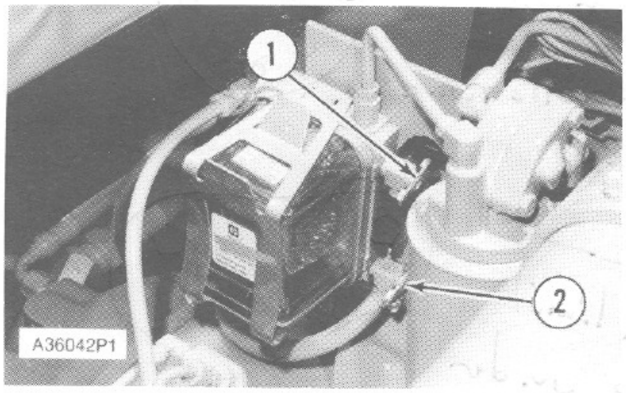
Water Separator

Some engines have a water separator. The water separator is installed between the fuel tank and the rest of the fuel system. For efficiency in the action of the water separator the fuel flow must come directly from the fuel tank and through the water separator. This is because the action of going through a pump or valves before the water separator lowers the efficiency of the water separator.

The water separator can remove 95% of the water in a fuel flow of up to 125 liter/hr (33 gph) if the concentration of the water in the fuel is 10% or less. It is important to check the water level in the water separator frequently. The maximum amount of water which the water separator can hold is 0.4 liter (.8 pt). At this point the water fills the glass to 3/4 full. Do not let the water separator have this much water before draining the water. After the water level is at 3/4 full, the water separator loses its efficiency and the water in the fuel can go through the separator and cause damage to the fuel injection pump.

Drain the water from the water separator every day or when the water level gets to ½ full. This gives the system protection from water in the fuel. If the fuel has a high concentration of water, or if the flow rate of fuel through the water separator is high, the water separator fills with water faster and must be drained more often.

To drain the water separator, open drain valve (2) in the drain line and vent valve (1) at the top of the water separator. Let the water drain until it is all out of the water separator. Close both valves.



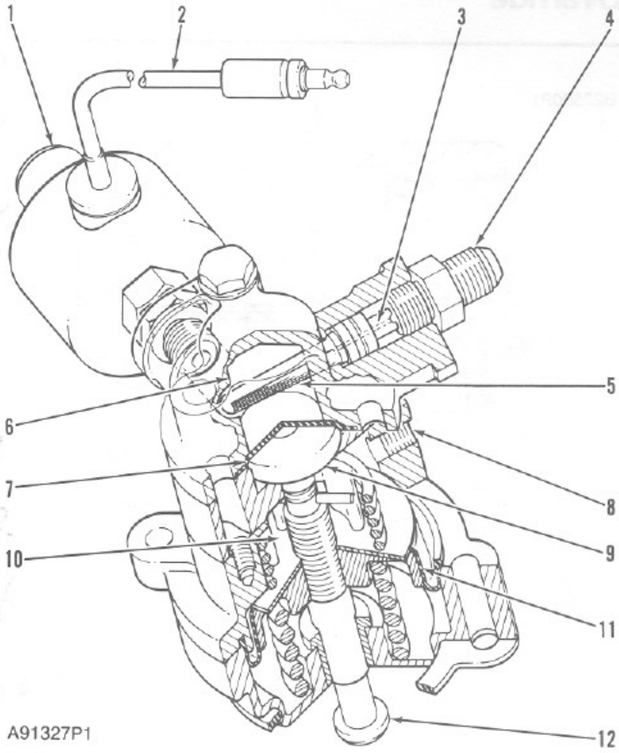
Water Separator
(1) Vent valve. (2) Drain valve.

Fuel Ratio Control With Hydraulic Override

NOTE: The hydraulic override was added to the fuel ratio control to permit easier cold weather starting.

The fuel ratio control limits the amount of fuel to the cylinders during an increase of engine speed (acceleration) to reduce exhaust smoke. The hydraulic override allows a maximum amount of fuel to the cylinders to start the engine.

Bolt (12) in the fuel ratio control limits travel of the fuel control shaft in the FUEL ON direction only. As the engine accelerates, the fuel control shaft makes contact with bolt (12) and will not go to the full fuel position. When the turbocharger gives enough air pressure to give good combustion in the cylinders, the inlet manifold pressure goes through a line to air inlet (8) into air chamber (10). The air pressure in air chamber (10) pushes on diaphragm (11) which moves bolt (12) down. When bolt (12) moves down, the fuel control shaft can move to the full fuel position.



Fuel Ratio Control
(1) Solenoid. (2) Wire. (3) Orifice. (4) Fitting (oil outlet). (5) Screen. (6) Oil chamber. (7) Diaphragm. (8) Air inlet. (9) Plunger. (10) Air chamber. (11) Diaphragm. (12) Bolt.

Wire (2) from solenoid (1) is connected to the start terminal of the starter switch. When the solenoid is activated by the starter switch, oil from the rear of the right cylinder head goes through solenoid (1) to oil chamber (6). Oil pressure in oil chamber (6) pushes on diaphragm (7) and plunger (9) which moves bolt (12) down. The fuel control shaft can now go to the full fuel position for easier starting.

When the engine starts and the starter switch is released, solenoid (1) closes and stops oil flow to oil chamber (6). Oil in oil chamber (6) goes through screen (5), orifice (3), and fitting (4). Oil now goes through a tube and drains into the left cylinder head. With no oil pressure in oil chamber (6), bolt (12) and plunger (9) move up. Bolt (12) will now limit the movement of the fuel control shaft until inlet manifold air pressure moves bolt (12) down.

C Fuel Ratio Control Without Hydraulic Override

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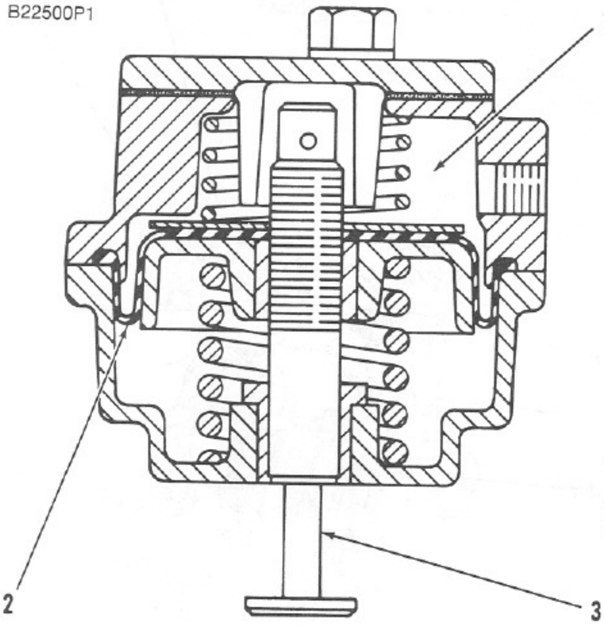
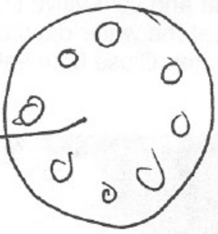
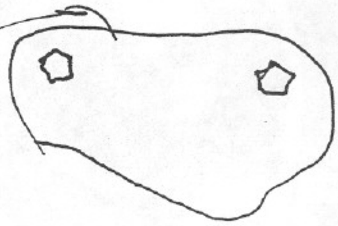


Holds off Full Fuel until turbo kicks in - remove bolts and turn cover clockwise for more Fuel

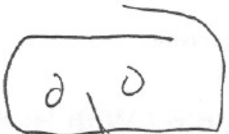
counter clockwise for less



Rack limit screw under this plate



Screw it down to limit



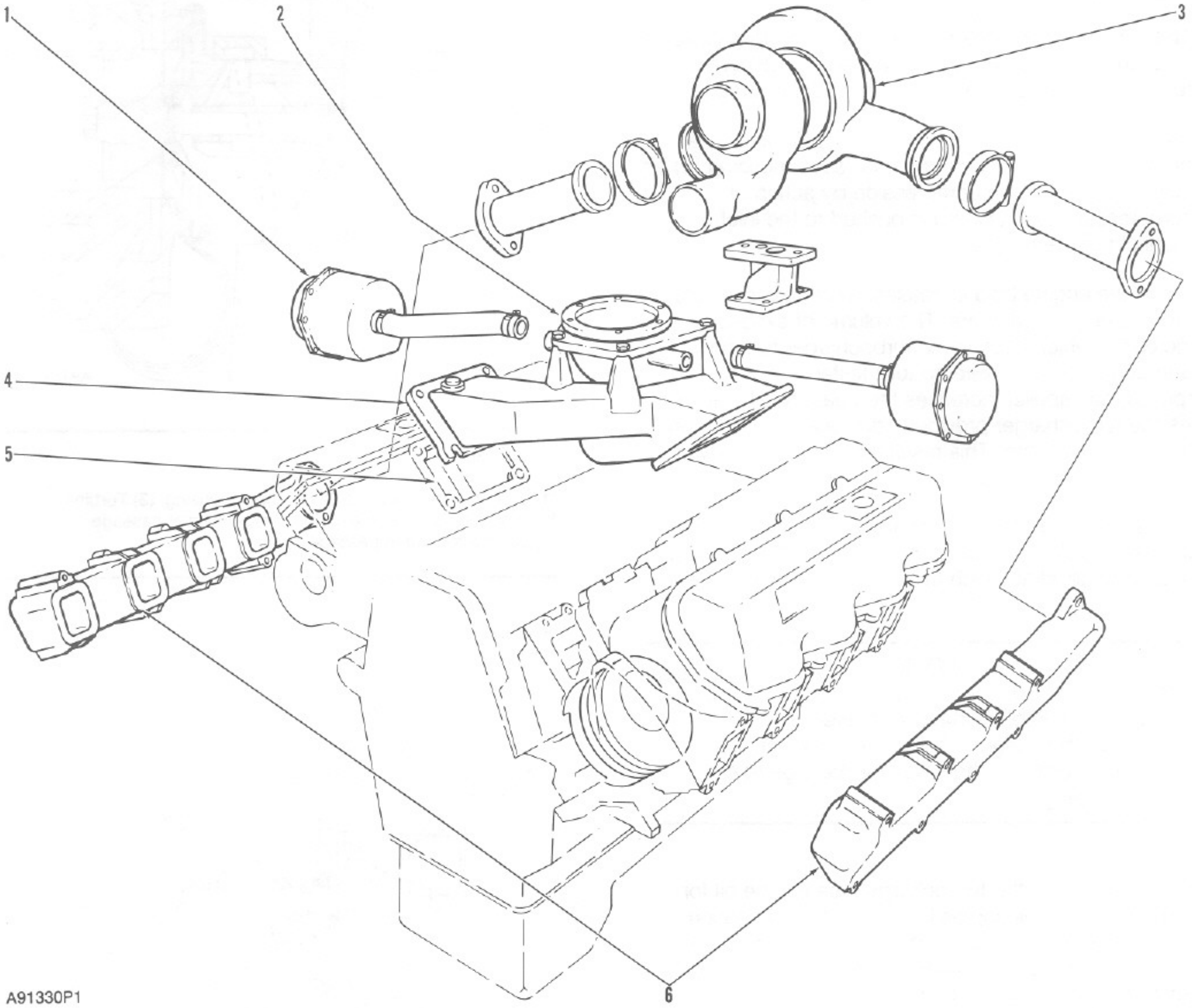
adj. Idle

Fuel Ratio Control
(1) Air Chamber. (2) Diaphragm. (3) Bolt.

The fuel ratio control limits the amount of fuel to the cylinders during an increase of engine speed (acceleration) to reduce exhaust smoke.

Bolt (3) in the fuel ratio control limits the travel of the fuel control shaft in the FUEL ON direction only. As the engine accelerates, bolt (3) will not let the fuel control shaft go to full fuel position. When the turbocharger gives enough air pressure to give good combustion in the cylinders, the inlet manifold pressure goes through a line into air chamber (1). The air pressure in air chamber (1) pushes on diaphragm (2) which moves bolt (3) down. When bolt (3) moves down, the fuel control shaft can move to the full fuel position.

Air Inlet And Exhaust System



Air Inlet And Exhaust System
(1) Positive crankcase ventilation valves. (2) Air cleaner adapter. (3) Turbocharger. (4) Air inlet pipe. (5) Inlet manifold. (6) Exhaust manifold.

The 3208 Turbocharged Engine has a turbocharger located at the rear of the engine. The exhaust gases from all of the cylinders are used to turn the turbocharger. Air is pulled through the air cleaner and adapter by the turbocharger compressor wheel. The air goes from the turbocharger through air inlet pipe (4) to the inlet manifold in each cylinder head. The air enters the cylinders when the intake valves open.

The exhaust gases go out of the cylinders and into the exhaust ports when the exhaust valves open. The exhaust then goes through the exhaust manifolds (6) to the turbocharger. The exhaust gases enter the turbocharger turbine housing and cause the turbine wheel to turn. The exhaust gases leave the turbocharger through the exhaust outlet.

There is a positive crankcase ventilation valve on each valve cover. The ventilation valves are connected to the air cleaner adapter on the air inlet side of the turbocharger.

Turbocharger

The turbocharger is supported by the mount at the rear of the engine. All the exhaust gases from the diesel engine go through the turbocharger.

The exhaust gases enter the turbine housing (3) and go through the blades of turbine wheel (4) causing the turbine wheel and compressor wheel (1) to turn.

When compressor wheel (1) turns, it pulls filtered air from the air cleaner through compressor housing (2) air inlet. The air is put in compression by action of compressor wheel (1) and is pushed to the inlet manifold of the engine.

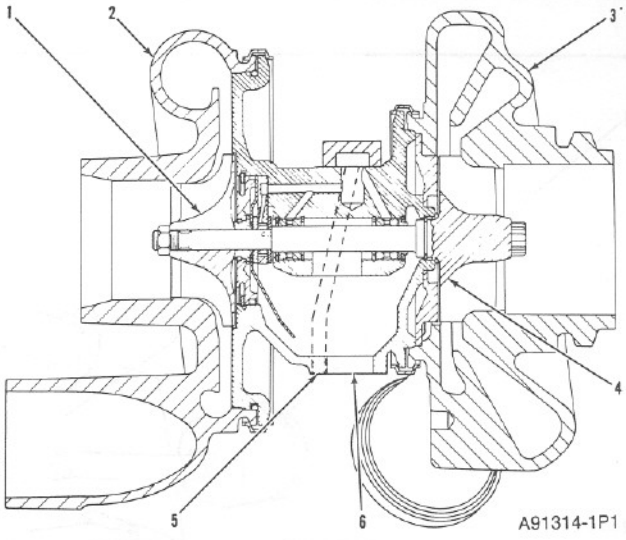
When the engine load increases, more fuel is injected into the engine cylinders. The volume of exhaust gas increases which causes the turbocharger turbine wheel and compressor impeller to turn faster. The increased rpm of the impeller increases the quantity of inlet air. As the turbocharger provides additional inlet air, more fuel can be burned. This results in more horsepower from the engine.

Maximum rpm of the turbocharger is controlled by the fuel setting, the high idle speed setting and the height above sea level at which the engine is operated.

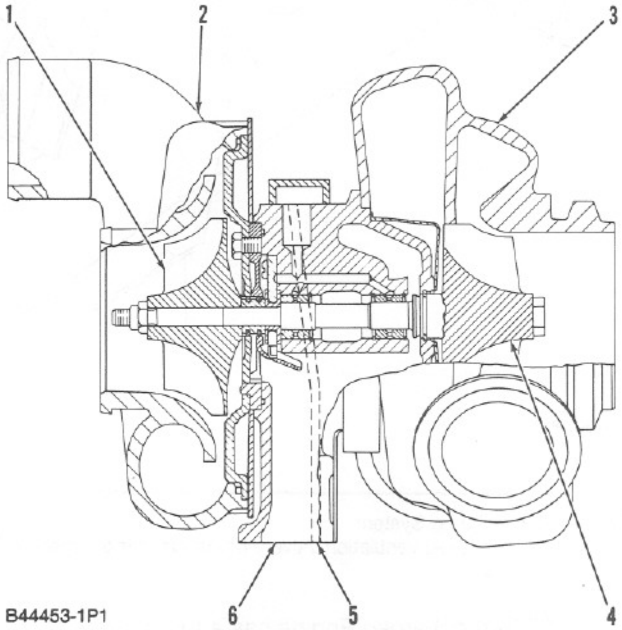
NOTICE

If the high idle rpm or the fuel setting is higher than given in the Fuel Setting And Related Information Fiche (for the height above sea level at which the engine is operated), there can be damage to engine or turbocharger parts.

The bearings for the turbocharger use engine oil for lubrication. The oil comes in through the lubrication inlet passage (5) and goes through passages in the center section for lubrication of the bearings. Oil from the turbocharger goes out through the lubrication outlet passage (6) in the bottom of the center section and goes back to the engine lubrication system.

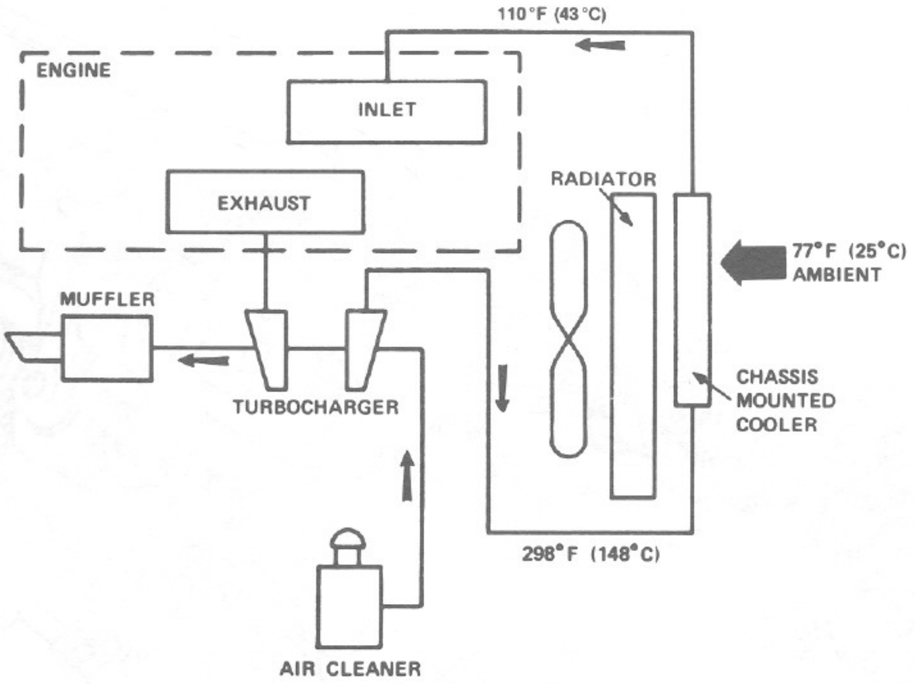


Turbocharger
(Schwitzer)
(1) Compressor wheel. (2) Compressor housing. (3) Turbine housing. (4) Turbine wheel. (5) Lubrication inlet passage.
(6) Lubrication outlet passage.



Turbocharger
(AiResearch)
(1) Compressor wheel. (2) Compressor housing. (3) Turbine housing. (4) Turbine wheel. (5) Lubrication inlet passage.
(6) Lubrication outlet passage.

Air To Air Aftercooled System

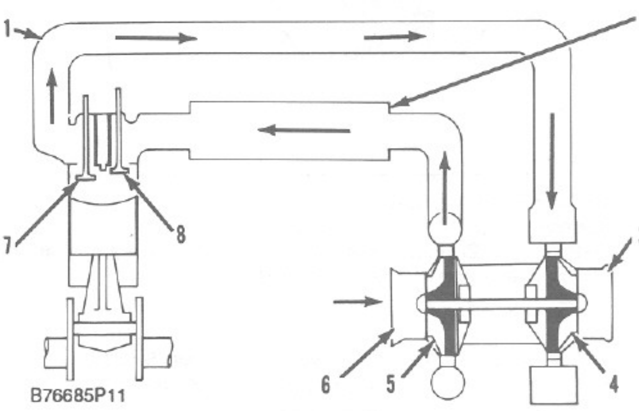

110°F (43°C)
ENGINE
INLET
EXHAUST
RADIATOR
77°F (25°C)
AMBIENT
MUFFLER
TURBOCHARGER
CHASSIS
MOUNTED
COOLER
298°F (148°C)
AIR CLEANER

C02000P1

Air To Air Aftercooled Schematic

In the air to air aftercooler system, compressed turbocharger air is directed to a chassis mounted cooler in front of the radiator. Ambient temperature air is moved across the aftercooler to lower the inlet air temperature to approximately 45°C (110°F). The air then goes to inlet manifold (2) which is part of the cylinder head. Cooling of the inlet air increases combustion efficiency, which helps to lower fuel consumption and increase horsepower output.

When intake valves (8) open, the air goes into the engine cylinder and is mixed with the fuel for combustion. When exhaust valves (7) open, the exhaust gases go out of the engine cylinder and into exhaust manifold (1). From the exhaust manifold, the exhaust gases go through the blades of the turbine wheel. This causes the turbine wheel and compressor wheel to turn. The exhaust gases then go out exhaust outlet (3) of the turbocharger.


1
2
3
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7
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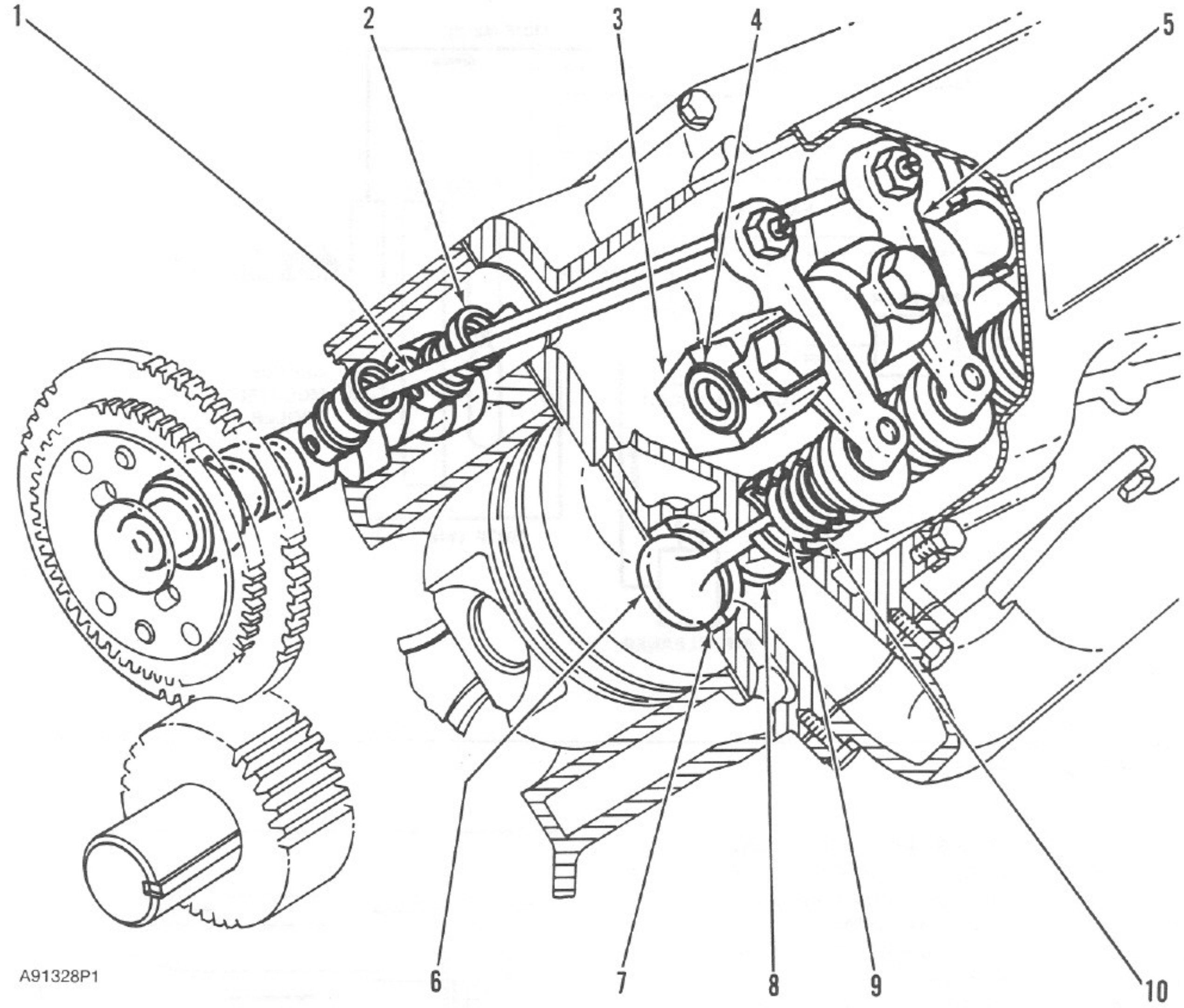
B76685P11

Air Inlet And Exhaust System Schematic

(1) Exhaust manifold. (2) Aftercooler/inlet manifold. (3) Exhaust outlet. (4) Turbine side of turbocharger. (5) Compressor side of turbocharger. (6) Air inlet. (7) Exhaust valve. (8) Intake valve.

c Cylinder Head And Valves



Cylinder Head And Valves
(Camshaft With Roller Lifter Shown)
(1) Push rod. (2) Lifter. (3) Guide support. (4) Rocker arm shaft. (5) Rocker arm. (6) Exhaust valve. (7) Valve seat insert. (8) Intake valve. (9) Inner valve spring. (10) Outer valve spring.

The valves and valve system components control the flow of inlet air and exhaust gases into and out of the cylinder during engine operation.

The intake and exhaust valves are opened and closed by movement of these components; crankshaft, camshaft, lifters, push rods, rocker arms, and valve springs. Rotation of the crankshaft causes rotation of the camshaft. The camshaft gear is driven by, and timed to, a gear on the front of the crankshaft. When the camshaft turns, the cams on the camshaft also turn and cause the lifters to go up and down. This movement makes the push rods move the rocker arms.

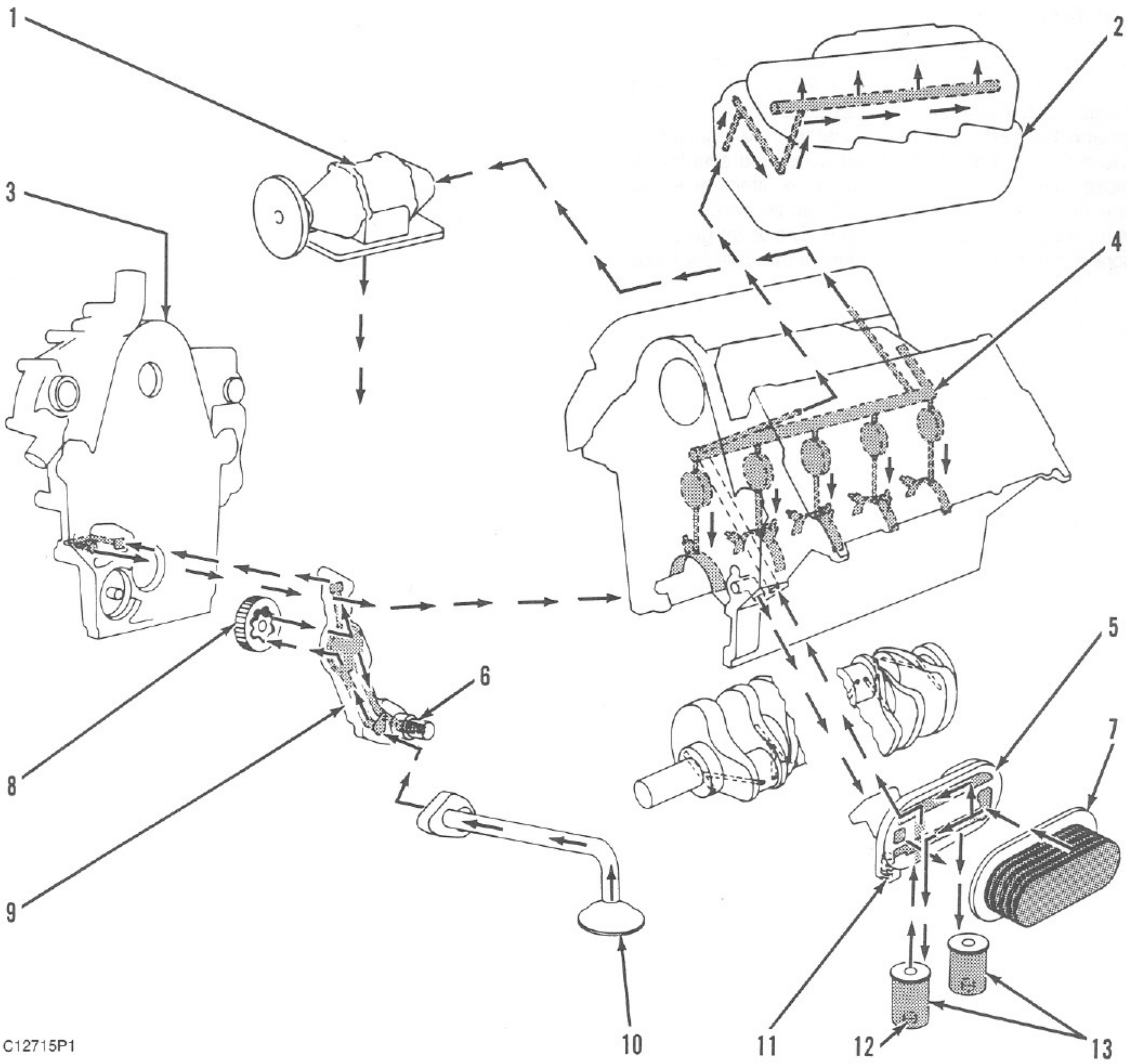
The movement of the rocker arms will make the intake and exhaust valves in the cylinder head open and close according to the firing order (injection sequence) of the engine. Two valve springs for each valve help to hold the valves in the closed position.

NOTE: Some 3208 engines have camshafts that use roller lifters and others have camshafts that use flat face lifters.

There is one intake and one exhaust valve for each cylinder. The valve seat insert for the exhaust valve can be replaced. The intake valve seat may be a replaceable seat insert or the seat may be machined and is part of the cylinder head. When the seat for the intake valve has been machined to the limits given in Specifications, the cylinder head can be bored (machined) for a valve seat insert. The valve guide bore is machined in and is a part of the cylinder head.

Lubrication System

(Engines With Oil Filter Bypass Valve In Oil Filter)



Schematic Of Lubrication System

(1) Vacuum pump or air compressor. (2) Cylinder head. (3) Front cover for the engine. (4) Oil manifold. (5) Base for the oil cooler. (6) Oil pump bypass valve. (7) Oil cooler. (8) Oil pump. (9) Cover for oil pump. (10) Suction bell for oil pump. (11) Oil cooler bypass valve. (12) Oil filter bypass valve. (13) Oil filters.

The lubrication system uses a six lobe, rotor type oil pump (8). Bolts hold the cover for the oil pump (9) on the front cover for the engine (3). The gear on the crankshaft drives the outer rotor. The outer rotor has rotation in a bearing in the front cover for the engine. The inner rotor goes on a short shaft in the front cover for the engine. The inner rotor is driven by the outer rotor.

Oil pump bypass valve (6), in the cover for the oil pump (9) controls the pressure of the oil coming from oil pump (8). The pump can put more oil into the system than needed. When the pressure of the oil going into the engine is more than 380 to 550 kPa (55 to 80 psi) the bypass valve (6) will open. This permits the oil that is not needed to bypass the system.

Oil from the oil pan is pulled through the suction bell for the oil pump (10) by oil pump (8). The oil is sent by the pump to an oil passage in the front cover for the engine (3). Oil from this passage goes to the cylinder block and on to the base for the oil cooler (5). The base for the oil cooler is on the left side of the engine, near the front of the engine. Oil cooler bypass valve (11) in the base for the oil cooler, will let the oil go around the oil cooler (7) when the oil is cold or if the restriction in the oil cooler is more than the other parts of the system. A difference in pressure of 85 to 105 kPa (12 to 15 psi) between the oil inlet and the oil outlet will open the bypass valve.

Oil from the oil cooler goes to the oil filters. Oil filter bypass valve (12) in the oil filters will let the oil go around the filters if there is a restriction in the filters.

There are two pressure outlets in the base for the oil cooler. The pressure outlets are on the outlet side of the oil cooler and oil filters. The pressure outlets are for the sending unit and switch for the oil pressure.

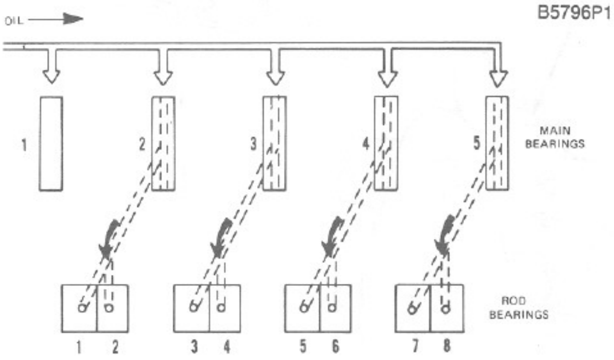
Oil from the oil filters (13) goes through a passage in the cylinder block to oil manifold (4). The oil manifold is in the center of the cylinder block, above the camshaft, and goes the full length of the cylinder block. Oil goes from the oil manifold to the bearings for the camshaft. There are grooves in the bores in the cylinder block around the bearings for the camshaft. The bearing surfaces (journals) on the camshaft get lubrication from these grooves through a hole in the bearings for the camshaft. Some of the oil goes aròund the grooves and down through a passage to a hole and groove in the top half of the main bearing. Oil from the hole and groove gives lubrication to the bearing surfaces (journals) of the crankshaft for the main bearings.

Oil gets into the crankshaft through holes in the bearing surfaces (journals) for the main bearings. Passages connect the bearing surface (journal) for the main bearing with the bearing surface (journal) for the connecting rod. The piston pins get lubrication from oil thrown by other parts.

Oil for the rocker arms comes from the oil manifold (4) through passages in the cylinder block. The passages in the cylinder block are in alignment with a passage in each cylinder head. The passage to the cylinder head on the left side is near the front of the cylinder block. The passage to the cylinder head on the right side is near the rear of the cylinder block.

The passage in each cylinder head sends the oil into an oil hole in the bottom of the mounting surface of the bracket that holds the shaft for the rocker arms. The oil hole is in the front bracket on the left side and in the rear bracket on the right side. The oil then goes up through the bracket and into the center of the shaft for the rocker arms. Oil goes along the center of the shaft to the bearings for the rocker arms. From the rocker arms, the oil is pushed through small holes to give lubrication to the valves, push rods, lifters, and camshaft lobes.

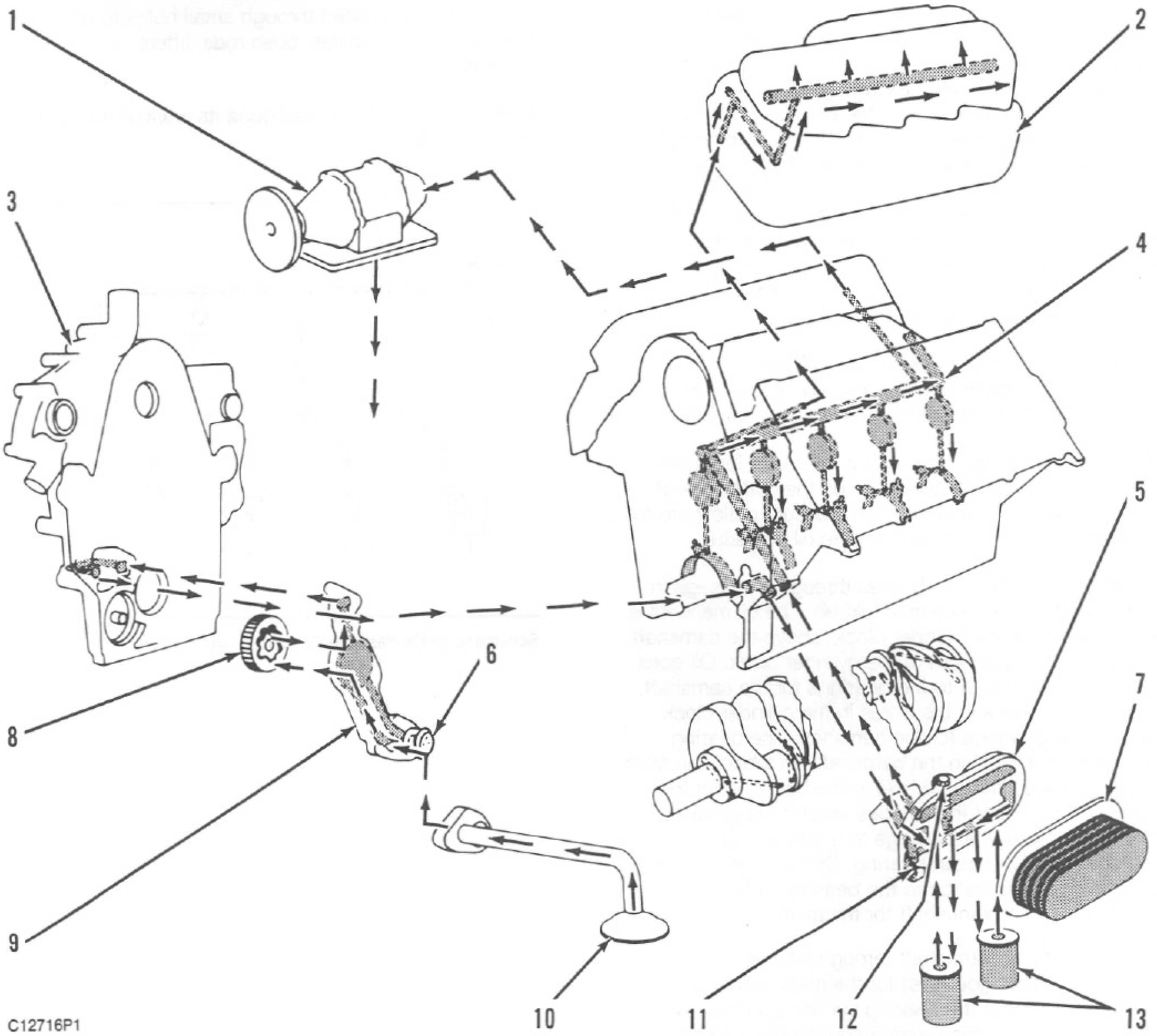
After the lubrication oil has done its work, it will return to the engine oil pan.



Schematic Of Oil Passages In Crankshaft

Lubrication System

(Engines With Oil Filter Bypass Valve In Oil Cooler Base)



Schematic Of Lubrication System
(1) Vacuum pump or air compressor. (2) Cylinder head. (3) Front cover for the engine. (4) Oil manifold. (5) Base for the oil cooler. (6) Oil pump bypass valve. (7) Oil cooler. (8) Oil pump. (9) Cover for oil pump. (10) Suction bell for oil pump. (11) Oil cooler bypass valve. (12) Oil filter bypass valve. (13) Oil filters.

The lubrication system uses a six lobe, rotor type oil pump (8). Bolts hold the cover for the oil pump (9) on the front cover for the engine (3). The gear on the crankshaft drives the outer rotor. The outer rotor has rotation in a bearing in the front cover for the engine. The inner rotor goes on a short shaft in front cover for the engine. The inner rotor is driven by the outer rotor.

Oil pump bypass valve (6), in the cover for the oil pump (9), controls the pressure of the oil coming from oil pump (8). The pump can put more oil into the system than needed. When the pressure of the oil going into the engine is more than 380 to 550 kPa (55 to 80 psi), the bypass valve (6) will open. This permits the oil that is not needed to bypass the system.

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Oil from the oil cooler goes to the oil filters. Oil filter bypass valve (12), in the base for the oil cooler will let oil go around oil filters (13) if there is a restriction in the oil filters.

There are two pressure outlets in the base for the oil cooler. The pressure outlets are on the outlet side of the oil cooler and oil filters. The pressure outlets are for the sending unit and switch for the oil pressure.

Oil from the oil filters (13) goes through a passage in the cylinder block to oil manifold (4). The oil manifold is in the center of the cylinder block, above the camshaft, and goes the full length of the cylinder block. Oil goes from the oil manifold to the bearings for the camshaft. There are grooves in the bore in the cylinder block around the bearings for the camshaft. The bearing surfaces (journals) on the camshaft get lubrication from these grooves through a hole in the bearings for the camshaft. Some of the oil goes around the grooves and down through a passage to a hole and groove in the top half of the main bearing. Oil from the hole and groove gives lubrication to the bearing surfaces (journals) of the crankshaft for the main bearings.

Oil gets into the crankshaft through holes in the bearing surfaces (journals) for the main bearings. Passages connect the bearing surface (journal) for the main bearing with the bearing surface (journal) for the connecting rod. The piston pins get lubrication from oil thrown by other parts.

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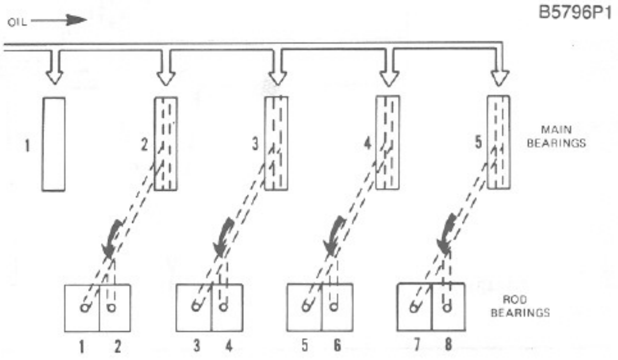
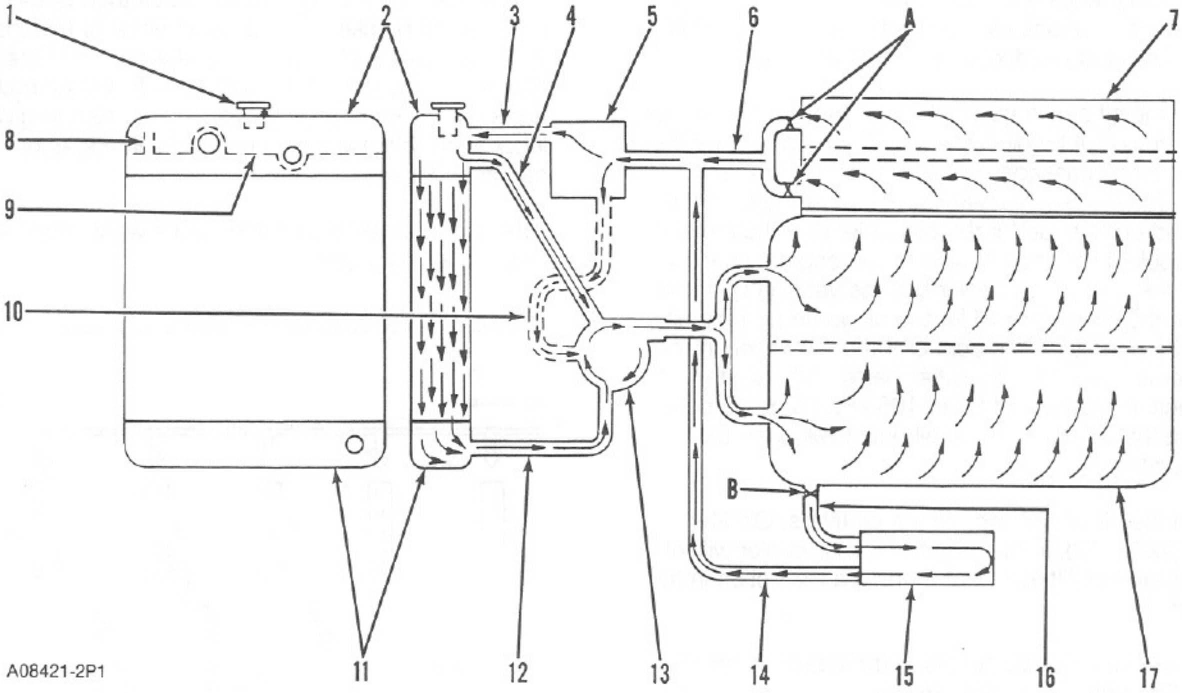
The passage in each cylinder head sends the oil into an oil hole in the bottom of the mounting surface of the bracket that holds the shaft for the rocker arms. The oil hole is in the front bracket on the left side and in the rear bracket on the right side. The oil then goes up through the bracket and into the center of the shaft for the rocker arms. Oil goes along the center of the shaft to the bearings for the rocker arms. From the rocker arms, the oil is pushed through small holes to give lubrication to the valves, push rods, lifters, and camshaft lobes.

After the lubrication oil has done its work, it will return to the engine oil pan.

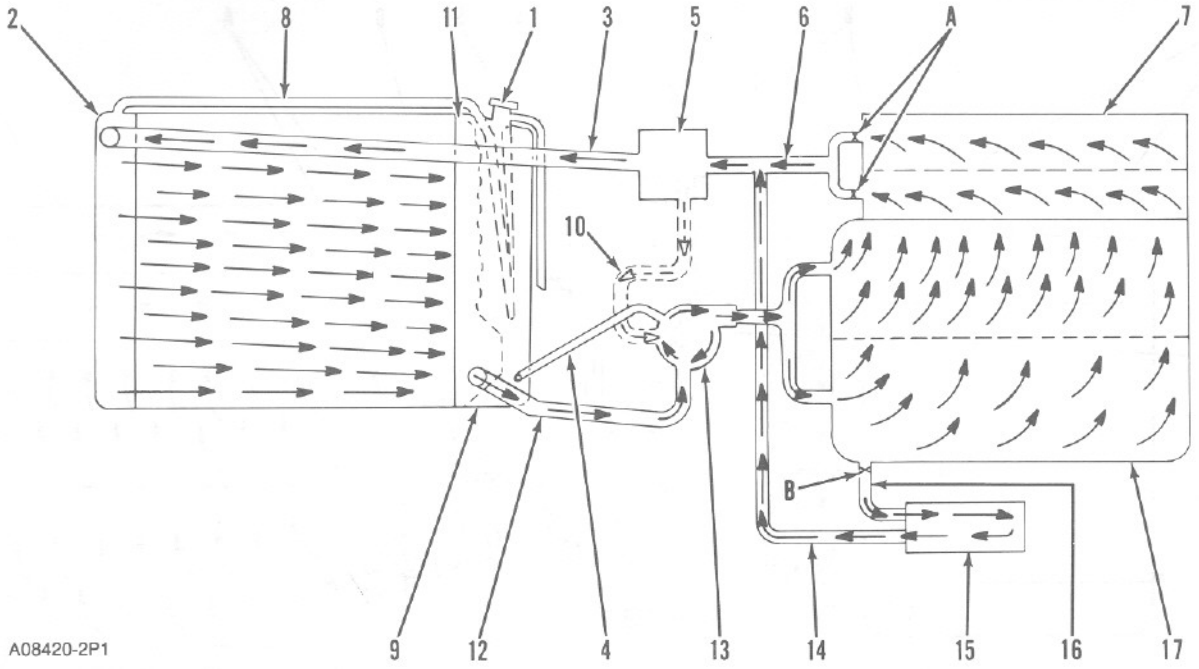


Schematic Of Oil Passages In Crankshaft

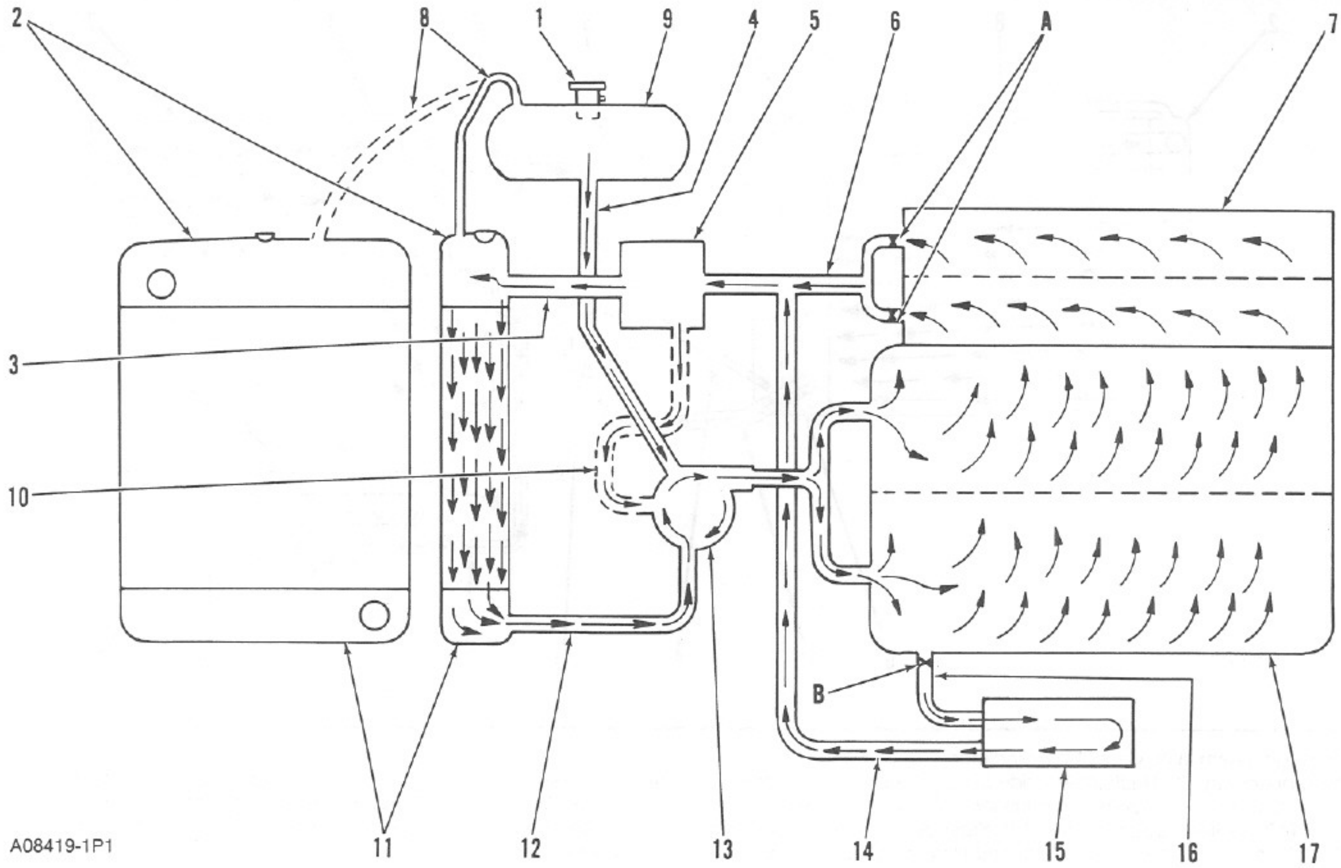
Cooling System



Cooling System With Standard Vertical Radiator
(1) Radiator cap. (2) Radiator top tank. (3) Radiator top hose. (4) Shunt line. (5) Housing for water temperature regulators. (6) Return to housing for water temperature regulators. (7) Cylinder heads (two). (8) Vent tube. (9) Surge tank. (10) Inside bypass. (11) Radiator bottom tank. (12) Radiator bottom hose. (13) Water pump. (14) Outlet line for oil cooler. (15) Oil cooler. (16) Inlet line for oil cooler. (17) Cylinder block. (A) Orifices between cylinder heads and front cover. (B) Orifice in oil cooler inlet.



Cooling System With Cross Flow Radiator
(1) Radiator cap. (2) Radiator left side tank. (3) Radiator top hose. (4) Shunt line. (5) Housing for water temperature regulators. (6) Return to housing for water temperature regulators. (7) Cylinder heads (two). (8) Vent tube. (9) Surge tank. (10) Inside bypass. (11) Radiator right side tank. (12) Radiator bottom hose. (13) Water pump. (14) Outlet line for oil cooler. (15) Oil cooler. (16) Inlet line for oil cooler. (17) Cylinder block. (A) Orifices between cylinder heads and front cover for the engine. (B) Orifice in oil cooler inlet.



Cooling System With Vertical Radiator And Separate Surge Tank
(1) Radiator cap. (2) Radiator top tank. (3) Radiator top hose. (4) Shunt line. (5) Housing for water temperature regulators. (6) Return to housing for water temperature regulators. (7) Cylinder heads (two). (8) Vent tube. (9) Surge tank. (10) Inside bypass. (11) Radiator bottom tank. (12) Radiator bottom hose. (13) Water pump. (14) Outlet line for oil cooler. (15) Oil cooler. (16) Inlet line for oil cooler. (17) Cylinder block. (A) Orifices between cylinder heads and front cover. (B) Orifice in oil cooler inlet.

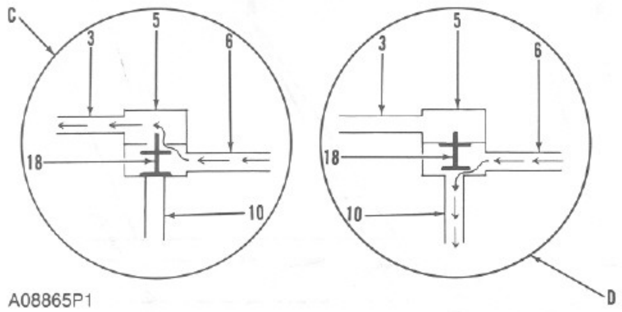
Water pump (13) is installed on the front face of the front cover for the engine and is driven by V-belts from the crankshaft pulley. The inlet opening of water pump (13) is connected to radiator bottom hose (12). The outlet flow of coolant from water pump (13) goes through inside passages in the front cover for the engine.

As the coolant goes from the water pump, it divides and goes through the inside passages in the front cover for the engine to cylinder block (17). Most of the coolant goes through cylinder block (17) and up to cylinder heads (7). From cylinder heads (7) the coolant goes forward through orifices (A) to the front cover for the engine.

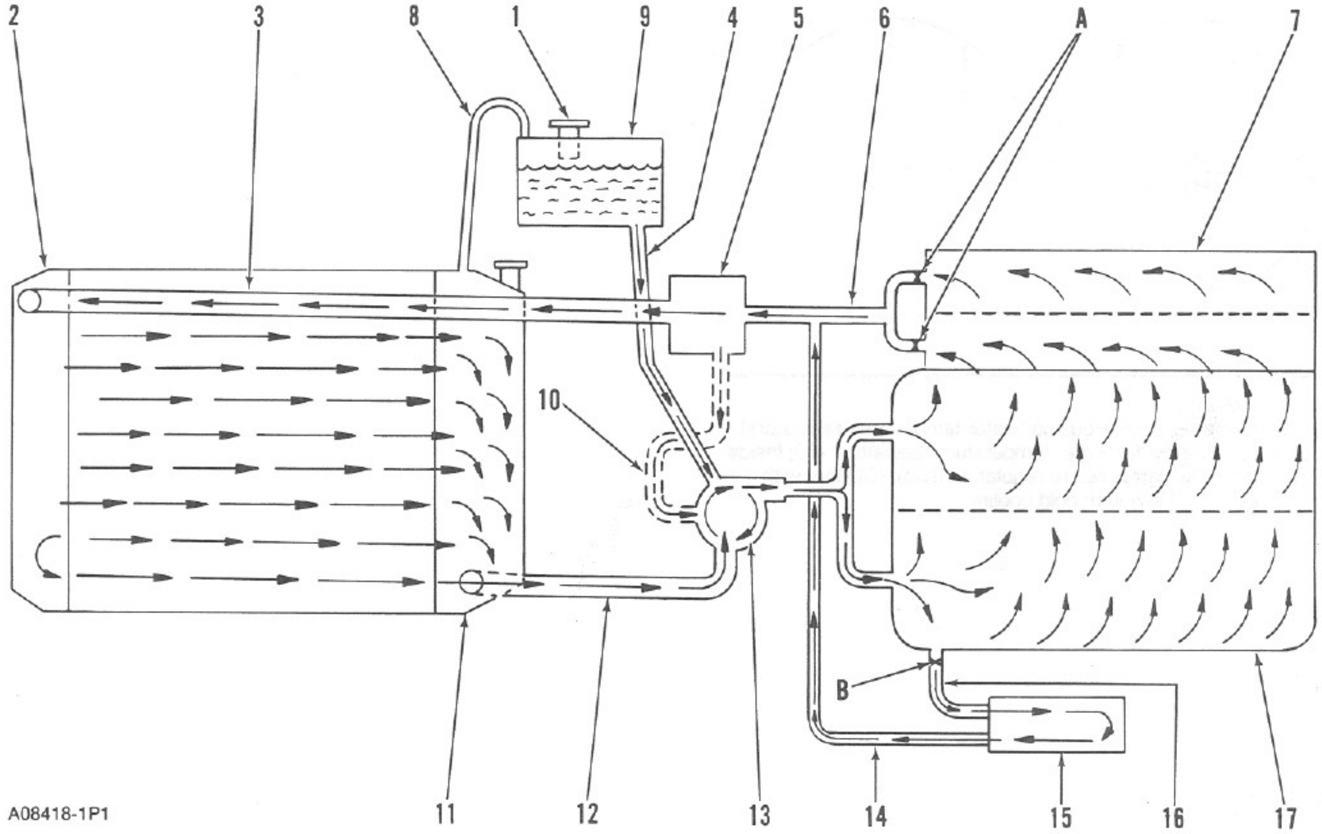
Part of the coolant going to the left side (as seen from the flywheel) of cylinder block (17) goes through orifice (B) to inlet line (16) and on to oil cooler (15), to cool the oil for lubrication of the engine, and back to the front cover for the engine through outlet line (14).

From the front cover for the engine, the coolant either goes to the inlet for water pump (13) or to the radiator.

If the coolant is cold (cool), the water temperature regulators (18) will be closed. The coolant will go through inside bypass (10) to water pump (13). If the coolant is warm, the water temperature regulators (18) will be open. When the water temperature regulators (18) are open, they make a restriction in the inside bypass (10) and the coolant goes through radiator top hose (3) and into radiator top tank (2) or left side tank (2). Coolant then goes through the core of the radiator to the radiator bottom tank (11) or radiator right side tank (11), where it is again sent through the cooling system. A small amount of coolant goes through inside bypass (10) when temperature regulators (18) are open.

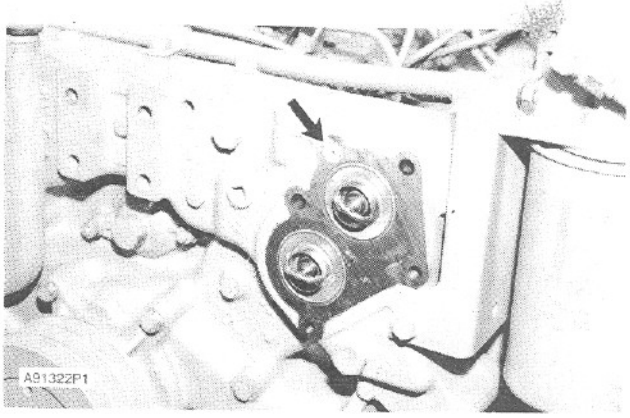


Flow Of Coolant
(3) Radiator top hose. (5) Housing (water temperature regulators). (6) Return to housing for water temperature regulators. (10) Inside bypass. (18) Water temperature regulators (two). (C) Flow with warm coolant. (D) Flow with cold coolant.



Cooling System With Cross Flow Radiator And Separate Surge Tank
(1) Radiator cap. (2) Radiator left side tank. (3) Radiator top hose. (4) Shunt line. (5) Housing for water temperature regulators. (6) Return to housing for water temperature regulators. (7) Cylinder heads (two). (8) Vent tube. (9) Surge tank. (10) Inside bypass. (11) Radiator right side tank. (12) Radiator bottom hose. (13) Water pump. (14) Outlet line for oil cooler. (15) Oil cooler. (16) Inlet line for oil cooler. (17) Cylinder block. (A) Orifices between heads and front cover. (B) Orifice in oil cooler inlet.

NOTE: The water temperature regulators (18) are an important part of the cooling system. They divide coolant flow between radiator (2) and inside bypass (10) as necessary to maintain the correct temperature. If the water temperature regulators are not installed in the system, there is no mechanical control, and most of the coolant will take the path of least resistance through the bypass. This will cause the engine to overheat in hot weather. In cold weather, even the small amount of coolant that goes through the radiator is too much, and the engine will not get to normal operating temperatures.

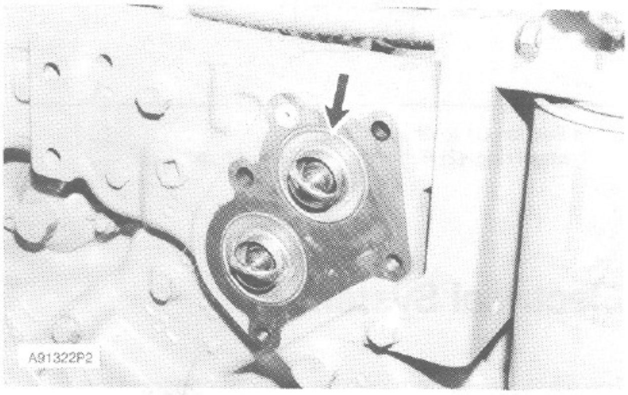


Location Of Water Temperature Regulators

The vertical radiator is made with a top tank (2) above the core and a surge tank (9) either above or separate from the top tank. Vent tube (8) connects radiator top tank (2) and surge tank (9). The cross flow radiator is made with a left side tank (2) and a right side tank (11), separated by an inside baffle, or a tank separate from the radiator. Vent tube (8) connects the surge tank (9) to the radiator.

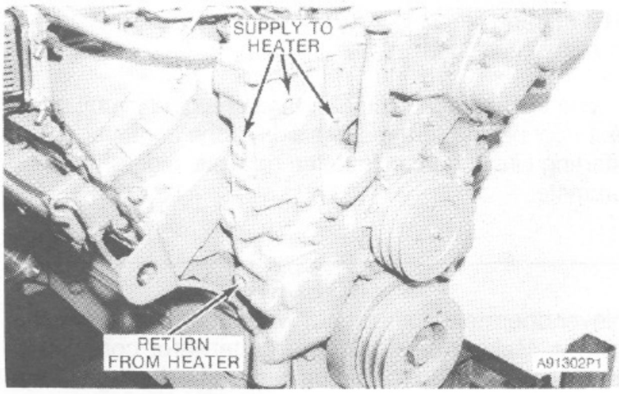
Surge tank (9) has a shunt line (4) that connects to the inlet of water pump (13). Shunt line (4) must always go down hill. This shunt type system keeps a positive pressure on the inlet of water pump (13) at all times. When putting coolant in the cooling system, coolant from surge tank (9) goes through shunt line (4) to the inlet of water pump (13) and fills cylinder block (17) from the bottom. By filling the system from the bottom, any air in the system is pushed out through radiator top tank (2), through vent tube (8) into surge tank (9).

Radiator cap (1) is used to keep the correct pressure in the cooling system. This pressure keeps a constant supply of coolant to water pump (13). If this pressure goes too high, a valve in radiator cap (1) moves (opens) to get a reduction of pressure. When the correct pressure is in the cooling system, the valve in radiator cap (1) moves down (to the closed position).



Location Of Vent Valve

The vent valve is located in the front housing next to the temperature regulators. The vent valve is used to let the air out of the cooling system when the cooling system is filled. When the engine is in operation, the vent valve will close and not let coolant go through. This will help increase the temperature of the coolant at low engine loads.



Locations Of Heater Connections

The front housing has several plugs that give access to water passages inside the housing. For the correct access points to install heater hoses, see the Locations Of Heater Connections picture.

Basic Block

Cylinder Block

The cylinders are a part of the cylinder block. There are no replaceable cylinder liners. The cylinders can be machined (bored) up to 1.02 mm (.040 in) oversize for reconditioning. The cylinders in the block are at a 90° angle to each other. There are five main bearings in the block to support the crankshaft.

Cylinder Head

There is one cylinder head for each side (bank) of the engine. One intake and one exhaust valve is used for each cylinder. The valve guides are a part of the cylinder head and can not be replaced. Valve seat inserts are used for the intake and exhaust valve and can be replaced.

C Pistons, Rings And Connecting Rods

The 3208 Truck engine uses both a two and a three ring piston. The two ring pistons have two rings which are located above the piston pin bore. There is one compression ring and one oil control ring. The oil ring is made in one piece and has an expansion spring behind it. The compression ring is also one piece and goes into an iron band that is cast into the piston. Both the compression and the oil control rings are of the conventional type (not Keystone).

The three ring piston is an aluminum casting with an iron band for the two compression rings. All rings are located above the piston pin bore. The two compression rings are of the Keystone type and seat in an iron band that is cast into the piston. Keystone rings have a tapered shape and the movement of the rings in the piston groove (also of tapered shape) results in a constantly changing clearance (scrubbing action) between the ring and the groove. This action results in a reduction of carbon deposit and possible sticking of rings. The oil ring is a standard (conventional) type and is spring loaded.

The piston pin is held in the piston by two snap rings which go into the piston pin bore.

Pistons with different compression ratios are used for 3208 Truck Engines. The pistons must not be interchanged with pistons of a different compression ratio.

The piston pin end of the connecting rod is tapered to give more bearing surface at the area of highest load. The rod is installed on the piston with the boss on the connecting rod on the same side as the crater in the piston. The connecting rod bearings are held in location with a tab that goes into a groove in the connecting rod.

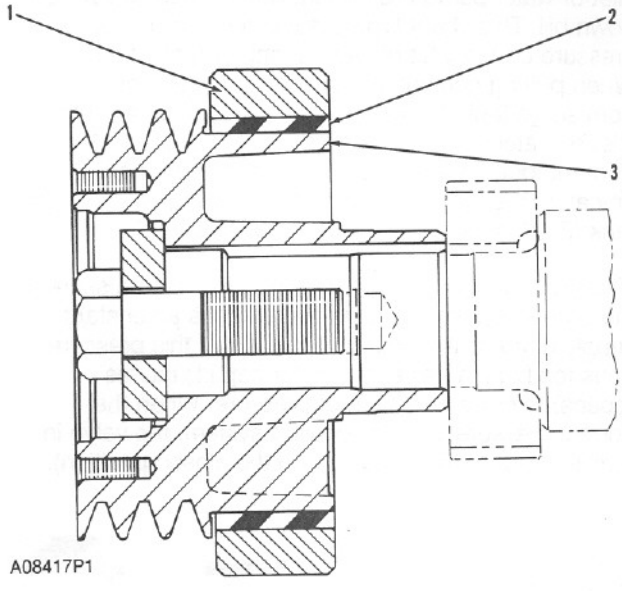
Crankshaft

The force of combustion in the cylinders is changed to usable rotating power by the crankshaft. The crankshaft can have either six or eight counterweights. A gear on the front of the crankshaft turns the engine camshaft gear and the engine oil pump. The end play of the crankshaft is controlled by the thrust bearing on No. 4 main bearing.

Vibration Damper

The twisting of the crankshaft, due to the regular power impacts along its length, is called twisting (torsional) vibration. The vibration damper is installed on the front end of the crankshaft. It is used for reduction of torsional vibrations and stops the vibration from building up to amounts that cause damage.

The damper is made of a flywheel ring (1) connected to an inner hub (3) by a rubber ring (2). The rubber makes a flexible coupling between the flywheel ring and the inner hub.



Cross Section Of A Vibration Damper
(1) Flywheel ring. (2) Rubber ring. (3) Inner hub.

Electrical System

The electrical system can have three separate circuits: the charging circuit, the starting circuit and the low amperage circuit. Some of the electrical system components are used in more than one circuit. The battery (batteries), circuit breaker, ammeter, cables and wires from the battery are all common in each of the circuits.

The charging circuit is in operation when the engine is running. An alternator makes electricity for the charging circuit. A voltage regulator in the circuit controls the electrical output to keep the battery at full charge.

The starting circuit is in operation only when the start switch is activated.

The low amperage circuit and the charging circuit are both connected to the same side of the ammeter. The starting circuit connects to the opposite side of the ammeter.

NOTICE

Never operate the alternator without the battery in the circuit. Making or breaking an alternator connection with heavy load on the circuit can cause damage to the regulator.

Charging System Components

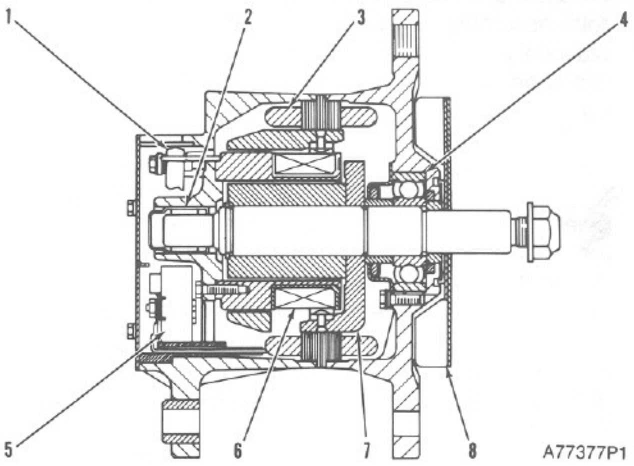
Alternator (Delco-Remy)

The alternator is driven by V-belts from the crankshaft pulley. This alternator is a three phase, self-rectifying charging unit, and the regulator is part of the alternator.

This alternator design has no need for slip rings or brushes, and the only part that has movement is the rotor assembly. All conductors that carry current are stationary. The conductors are the field winding, stator windings, six rectifying diodes and the regulator circuit components.

The rotor assembly has many magnetic poles like fingers with air space between each opposite pole. The poles have residual magnetism (like permanent magnets) that produce a small amount of magnet-like lines of force (magnetic field) between the poles. As the rotor assembly begins to turn between the field winding and the stator windings, a small amount of alternating current (AC) is produced in the stator windings from the small magnetic lines of force made by the residual magnetism of the poles. This AC current is changed to direct current (DC) when it passes through the diodes of the rectifier bridge. Most of this current goes to charge the battery and to supply the low amperage circuit, and the remainder is sent on to the field windings. The DC current flow through the field windings (wires around an iron core) now increases the strength of the magnetic lines of force. These stronger lines of force now increase the amount of AC current produced in the stator windings. The increased speed of the rotor assembly also increases the current and voltage output of the alternator.

The voltage regulator is a solid state (transistor, stationary parts) electronic switch. It feels the voltage in the system and switches on and off many times a second to control the field current (DC current to the field windings) for the alternator to make the needed voltage output.

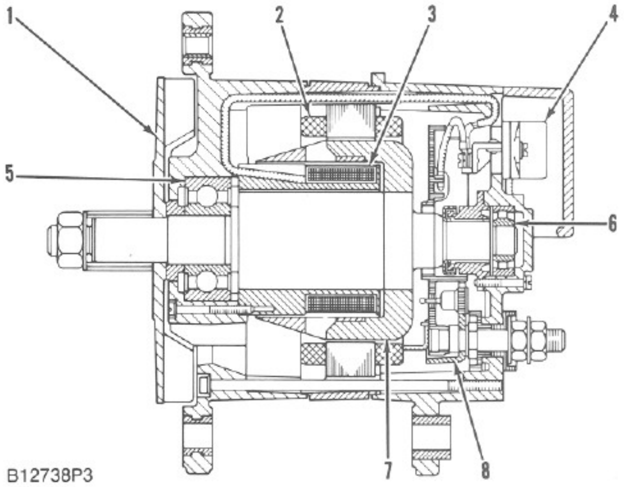


Delco-Remy Alternator
(1) Regulator. (2) Roller bearing. (3) Stator winding. (4) Ball bearing. (5) Rectifier bridge. (6) Field winding. (7) Rotor assembly. (8) Fan.

Alternator (Bosch)

The alternator is driven by V-belts from the crankshaft pulley. This alternator is a three phrase, self-rectifying charging unit, and the regulator is part of the alternator.

The 7N9720 Alternator has an output of 37A. The 9W3043 Alternator has an output of 40A.



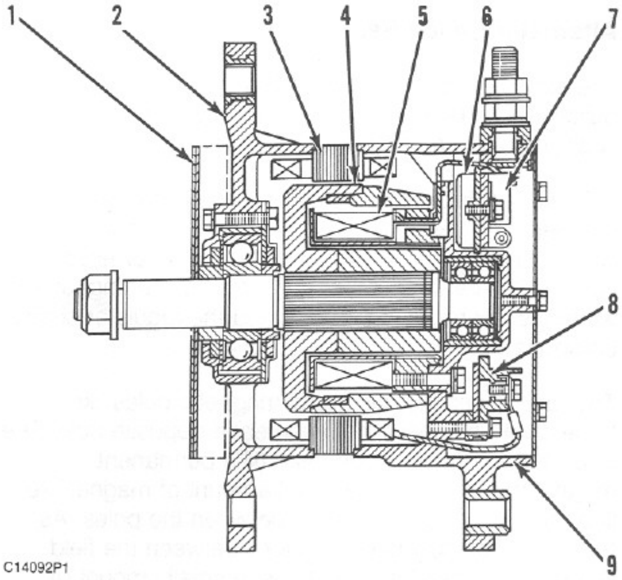
Bosch Alternator
(1) Fan. (2) Stator winding. (3) Field winding. (4) Regulator. (5) Ball bearing. (6) Roller bearing. (7) Rotor. (8) Rectifier assembly.

This alternator design has no need for slip rings or brushes, and the only part that has movement is the rotor assembly. All conductors that carry current are stationary. The conductors are: the field winding, stator windings, six rectifying diodes, and the regulator circuit components.

The rotor assembly has many magnetic poles like fingers with air space between each opposite pole. The poles have residual magnetism (like permanent magnets) that produce a small amount of magnet-like lines of force (magnetic field) between the poles. As the rotor assembly begins to turn between the field winding and the stator windings, a small amount of alternating current (AC) is produced in the stator windings from the small magnetic lines of force made by the residual magnetism of the poles. This AC current is changed to direct current (DC) when it passes through the diodes of the rectifier bridge. Most of this current goes to charge the battery and to supply the low amperage circuit, and the remainder is sent to the field windings. The DC current flow through the field windings (wires around an iron core) now increases the strength of the magnetic lines of force. These stronger lines of force now increase the amount of AC current produced in the stator windings. The increased speed of the rotor assembly also increases the current and voltage output of the alternator.

Alternator (Nippondenso)

The Nippondenso alternator has three-phase, full-wave rectified output. It is brushless. The rotor and bearings are the only moving parts. There is a 24 volt, 9G4574 Alternator with 35 amp output and a 12 volt, 8T9900 Alternator with a 55 amp output.



9G4574 Nippondenso Alternator
(1) Fan. (2) Front frame assembly. (3) Stator assembly. (4) Rotor assembly. (5) Field winding (coil assembly). (6) Regulator assembly. (7) Condenser (suppression capacitor). (8) Rectifier assembly. (9) Rear frame assembly.

When the engine is started and the rotor turns inside the stator windings, three-phase alternating current (AC) and rapidly rising voltage is generated.

A small amount of alternating current (AC) is changed (rectified) to pulsating direct current (DC) by the exciter diodes on the rectifier assembly. Output current from these diodes adds to the initial current which flows through the rotor field windings from residual magnetism. This will make the rotor a stronger magnet and cause the alternator to become activated automatically. As rotor speed, current and voltages increase, the rotor field current increases enough until the alternator becomes fully activated.

The main battery charging current is charged (rectified) from AC to DC by the other positive and negative diodes in the rectifier and pack (main output diodes) which operate in a full wave linkage rectifier circuit.

Alternator output is controlled by a regulator, which is inside the alternator rear frame.

Alternator Regulator (Bosch)

The voltage regulator is an electronic switch. It feels the voltage in the system and gives the necessary field current (current to the field windings of the alternator) for the alternator to make the needed voltage. The voltage regulator controls the field current to the alternator by switching on and off many times a second.

Alternator Regulator (Nippondenso)

The regulator is fastened to the alternator by two different methods. One method fastens the regulator to the top, rear of alternator. With the other method the regulator is fastened separately by use of a wire and a connector that goes into the alternator.

The voltage regulator is a solid state electronic switch. It feels the voltage in the system and gives the necessary field current (current to the field windings of the alternator) for the alternator to make the needed voltage. The voltage regulator controls the field current to the alternator by switching on and off many times a second. There is no voltage adjustment for this regulator.

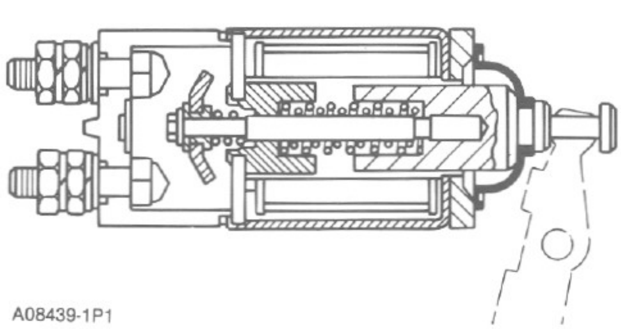
Starting System Components

Solenoid

A solenoid is a magnetic switch that does two basic operations:

a. Closes the high current starter motor circuit with a low current start switch circuit.

b. Engages the starter motor pinion with the ring gear.



Typical Solenoid Schematic

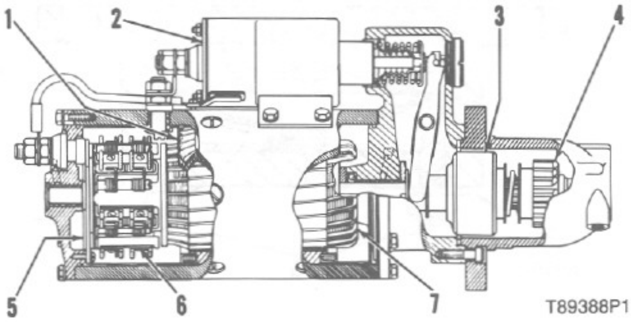
The solenoid switch is made of an electromagnetic (one or two sets of windings) around a hollow cylinder. There is a plunger (core) with a spring load inside the cylinder that can move forward and backward. When the start switch is closed and electricity is sent through the windings, a magnetic field is made that pulls the plunger forward in the cylinder. This moves the shift lever (connected to the rear of the plunger) to engage the pinion drive gear with the ring gear. The front end of the plunger then makes contact across the battery and motor terminals of the solenoid, and the starter motor begins to turn the flywheel of the engine.

When the start switch is opened, current no longer flows through the windings. The spring now pushes the plunger back to the original position, and, at the same time, moves the pinion gear away from the flywheel.

When two sets of windings in the solenoid are used, they are called the hold-in winding and the pull-in winding. Both have the same number of turns around the cylinder, but the pull-in winding uses a larger diameter wire to produce a greater magnetic field. When the start switch is closed, part of the current flows from the battery through the hold-in windings, and the rest flows through the pull-in windings to motor terminal, then through the motor to ground. When the solenoid is fully activated (connection across battery and motor terminal is complete), current is shut off through the pull-in windings. Now only the smaller hold-in windings are in operation for the extended period of time it takes to start the engine. The solenoid will now take less current from the battery, and heat made by the solenoid will be kept at an acceptable level.

Starter Motor

The starter motor is used to turn the engine flywheel fast enough to get the engine running.



Starter Motor
(1) Field. (2) Solenoid. (3) Clutch. (4) Pinion. (5) Commutator. (6) Brush assembly. (7) Armature.

The starter motor has a solenoid. When the start switch is turned to the START position, the solenoid will be activated electrically. The solenoid core will now move to push the starter pinion, by a mechanical linkage, to engage with the ring gear on the flywheel of the engine. The starter pinion will engage with the ring gear before the electric contacts in the solenoid close the circuit between the battery and the starter motor. When the circuit between the battery and the starter motor is complete, the pinion will turn the engine flywheel. A clutch gives protection for the starter motor so that the engine, when it starts to run, cannot turn the starter motor too fast. When the start switch is released, the starter pinion will move away from the flywheel ring gear.

Magnetic Switch

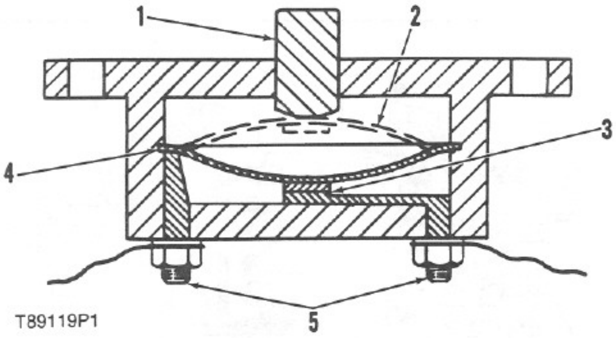
A magnetic switch (relay) is used sometimes for the starter solenoid circuit. Its operation electrically is the same as the solenoid. Its function is to reduce the current load on the start switch and control current to the starter solenoid.

Other Components

Circuit Breaker

The circuit breaker is a switch that opens the battery circuit if the current in the electrical system goes higher than the rating of the circuit breaker.

A heat activated metal disc with a contact point completes the electric circuit through the circuit breaker. If the current in the electrical system gets too high, it causes the metal disc to get hot. This heat causes a distortion of the metal disc which opens the contacts and breaks the circuit. A circuit breaker that is open can be reset after it cools. Push the reset button to close the contacts and reset the circuit breaker.



Circuit Breaker Schematic
(1) Reset button. (2) Disc in open position. (3) Contacts. (4) Disc. (5) Battery circuit terminals.

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Testing And Adjusting

Fuel System

Either too much fuel or not enough fuel for combustion can be the cause of a problem in the fuel system.

Many times work is done on the fuel system when the problem is really with some other part of the engine. The source of the problem is difficult to find, especially when smoke comes from the exhaust. Smoke that comes from the exhaust can be caused by a bad fuel injection valve, but it can also be caused by one or more of the reasons that follow:

a. Not enough air for good combustion.

b. An overload at high altitude.

c. Oil leakage into combustion chamber.

d. Not enough compression.

Fuel System Inspection

A problem with the components that send fuel to the engine can cause low fuel pressure. This can decrease engine performance.

1. Check the fuel level in the fuel tank. Look at the cap for the fuel tank to make sure the vent is not filled with dirt.
2. Check the fuel lines for fuel leakage. Be sure the fuel supply line does not have a restriction or a bad bend.
3. Install a new fuel filter. Clean the fuel screen located in the inlet valve of the fuel transfer pump.
4. Remove any air that may be in the fuel system. Open the drain valve on the fuel injection pump housing. Operate the fuel priming pump until fuel without air comes from the drain lines. Close the drain valve.

To remove air from the fuel injection lines, loosen the fuel line nuts 1/2 turn. Move the governor lever to the low idle position. Crank the engine with the starter motor until fuel without air comes from the fuel line connections. Tighten the fuel line nuts.

Check Engine Cylinders Separately

An easy check can be made to find the cylinder that runs rough (misfires) and causes black smoke to come out of the exhaust pipe.

Run the engine at the speed that is the roughest. Loosen the fuel line nut at a fuel injection pump. This will stop the flow of fuel to that cylinder. Do this for each cylinder until a loosened fuel line is found that makes no difference in engine performance. Be sure to tighten each fuel line nut after the test before the next fuel line nut is loosened. Check each cylinder by this method. When a cylinder is found where the loosened fuel line nut does not make a difference in engine performance, test the injection pump and fuel injection nozzle for that cylinder.

Temperature of an exhaust manifold port, when the engine runs at low idle speed, can also be an indication of the condition of a fuel injection nozzle. Low temperature at an exhaust manifold port is an indication of no fuel to the cylinder. This can possibly be an indication of a nozzle with a defect. Extra high temperature at an exhaust manifold port can be an indication of too much fuel to the cylinder, also caused by a nozzle with a defect.

The most common defects found with the fuel injection valves are:

1. Carbon on tip of the nozzle or in the nozzle orifice.
2. Orifice wear.
3. Dirty nozzle screen.

Fuel Injector Testing

Testing of the injectors must be done off the engine. Use 5P4150 Nozzle Testing Group. For use of the 5P4150 Nozzle Testing Group, refer to Special Instruction, Form No. SEHS7292.

Fuel Injection Lines

Fuel from the fuel injection pumps goes to the fuel injection nozzles through the fuel injection lines.

When fuel injection lines are disconnected or removed, always put caps or plugs on the ends to keep dirt out of the lines. When fuel injection lines are installed, be sure all clamps and dampers are installed in their original location.

Each fuel injection line of an engine has a special design and must be installed in a certain location. When fuel injection lines are removed from an engine, put identification marks or tags on the fuel lines as they are removed, so they can be put in the correct location when they are installed.

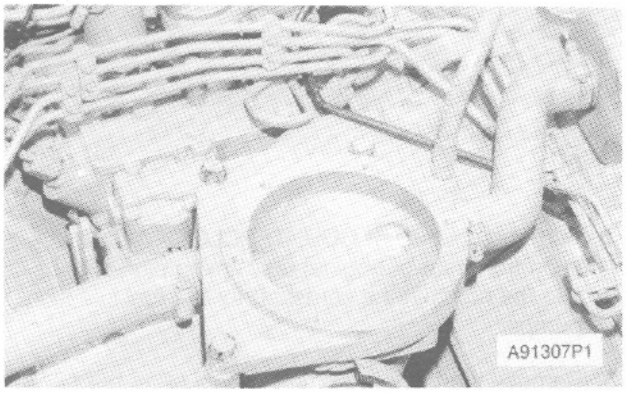
The nuts that hold a fuel injection line to an injection nozzle and injection pump must be tightened to the correct torque. If the nut is loose, fuel will leak from the connection. If the nut is tightened too tight, the inside diameter of the line will become smaller and cause a restriction to the flow of fuel in the line. Use a torque wrench and a 5P144 Fuel Line Socket to tighten the fuel injection line nuts to 42 ± 7 N•m (31 ± 5 lb ft).

Fuel Injection Pumps

When injection pumps, sleeves and lifters are removed from the injection pump housing, keep the parts of each pump together so they can be installed back in their original location.

Be careful when disassembling injection pumps. Do not damage the surface on the plunger. The plunger, sleeve and barrel for each pump are made as a set. Do not put the plunger of one pump in the barrel or sleeve of another pump. If one part is worn, install a complete new pump assembly. Be careful when putting the plunger in the bore of the barrel or sleeve.

When an injection pump is installed correctly, the plunger is through the sleeve and the adjustment lever is engaged with the groove on the sleeve. The bushing that holds the injection pump in the pump housing must be kept tight. Tighten the bushing to 80 ± 7 N•m (60 ± 5 lb ft). Damage to the housing will result if the bushing is too tight. If the bushing is not tight enough, the pump will leak.



Air Inlet Pipe

NOTICE

If the sleeves on one or more of the fuel injection pumps have been installed wrong, damage to the engine is possible if cautions are not taken at first starting. When the fuel injection pumps have been removed and installed with the fuel injection pump housing on engine, take the following cautions when first starting the engine.

---

a. Remove the air cleaner leaving the air inlet pipe open as shown.
b. Set the governor control at low idle.

⚠ WARNING

Be careful when plate is put against air inlet opening. Due to excessive suction, the plate can be pulled quickly against air inlet pipe. To avoid crushed fingers, do not put fingers between plate and air inlet pipe.

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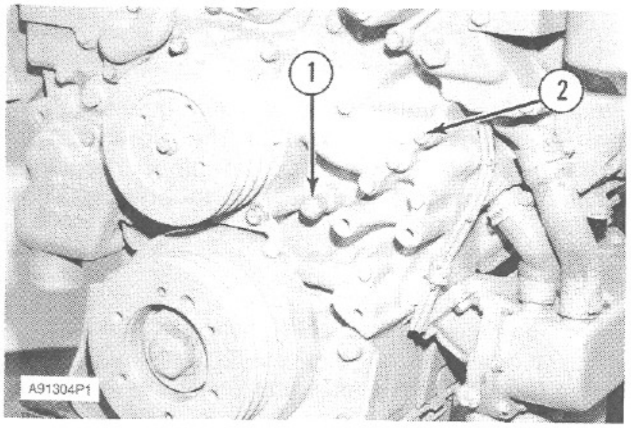
c. Start the engine, and if engine starts to overspeed (run out of control), put a steel plate over the air inlet as shown to stop the engine.

Stopping The Engine

Finding Top Center Compression Position For No. 1 Piston

No. 1 piston at top center (TDC) on the compression stroke is the starting point for all timing procedures.

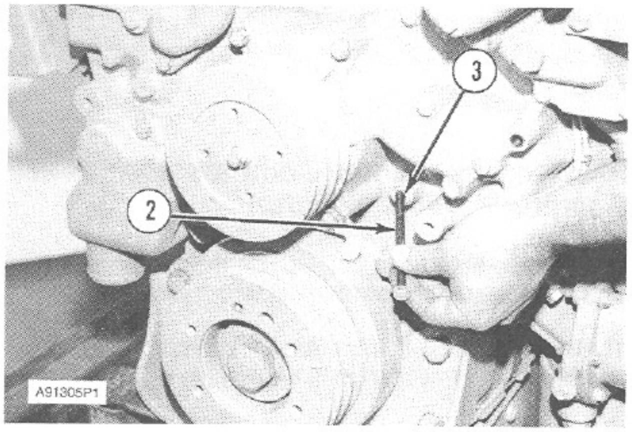
1. Remove fitting (1) from the timing hole (3) in the front cover. Put bolt (2) in timing hole (3).



Fitting And Bolt Location
(1) Fitting. (2) Bolt.

2. Turn the crankshaft COUNTERCLOCKWISE (as seen from rear of engine) until bolt (2) will go into the hole in the drive gear for the camshaft.

3. Remove the valve cover on the right side of the engine (as seen from rear of engine). The two valves at the right front of the engine are the intake and exhaust valves for No. 1 cylinder.



Installing Bolt
(2) Bolt. (3) Timing hole.

4. The intake and exhaust valves for No. 1 cylinder must now be closed and the timing pointer will be in alignment with the TDC-1 on the damper assembly. The No. 1 piston is now at top center on the compression stroke.

Fuel System Adjustments

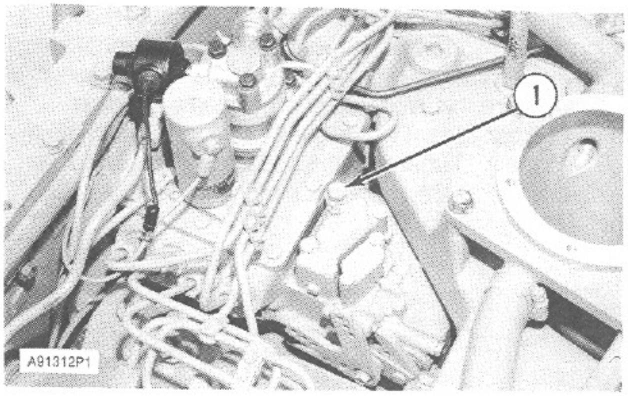
Checking Fuel Injection Pump Timing; On Engine

The timing of the fuel injection pump can be checked and changed if necessary, to make compensation for movement in the taper sleeve drive or worn timing gears. The timing can be checked and if necessary, changed using the following method.

Checking Timing by Timing Pin Method

Tools Needed		
6V4069	Puller	1
3P1544	Timing Pin	1

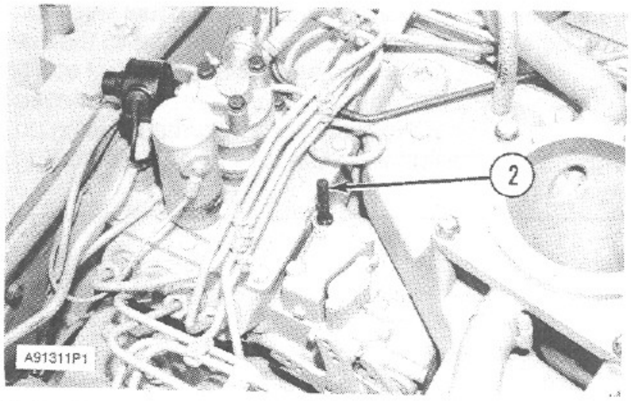
1. Remove bolt (1) from the timing pin hole.



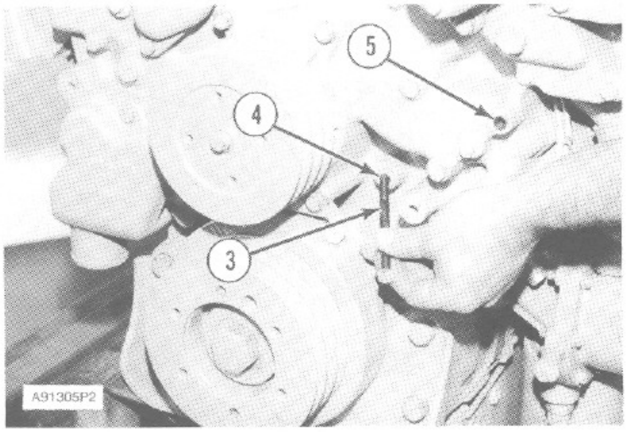
Timing Hole Bolt
(1) Bolt.

2. Turn the crankshaft COUNTERCLOCKWISE (as seen from rear of engine) until timing pin (2) goes into the notch in the camshaft for the fuel injection pumps.

3. Remove the fitting from timing hole (4) in the front cover. Put bolt (3) through the front cover and into the hole with threads in the timing gear. The bolt from hole (5) can be used.



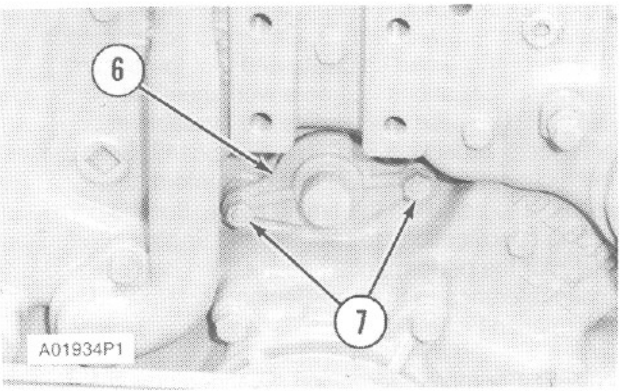
Timing Pin Installed
(2) 3P1544 Timing Pin.



Installing Bolt
(3) 1D4539 Bolt, 5/16 in-18 NC, 63.5 mm (2.5 in) long. (4) Timing hole. (5) Hole.

4. If the timing pin is in the notch in the camshaft for the fuel injection pumps, and bolt (3) goes into the hole in the timing gear through timing hole (4), the timing of the fuel injection pump is correct.

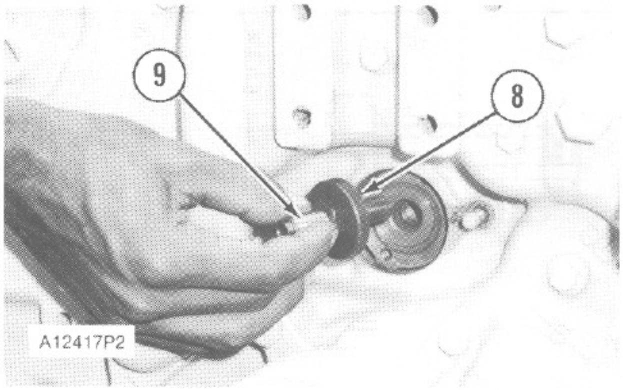
NOTE: If bolt (3) does not go in the hole in the timing gear with timing pin (2) in the notch in the camshaft, use the procedure that follows.



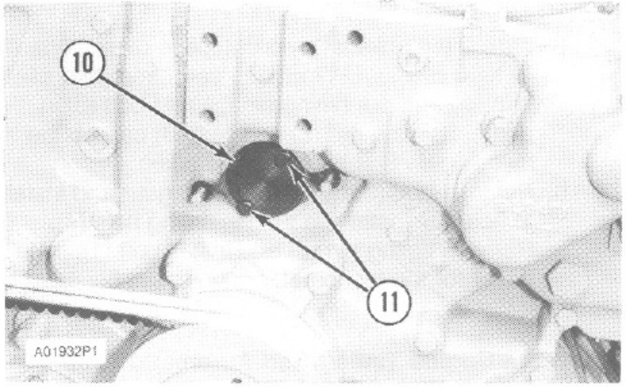
Location Of Cover
(6) Cover for the tachometer drive assembly. (7) Nuts.

a. Remove nuts (7) and the cover for the tachometer drive assembly (6).
b. Remove the tachometer drive shaft (9) and washer (8) from the camshaft for the fuel injection pumps.

NOTE: Tachometer drive shaft (9) and washer (8) are removed as an assembly.

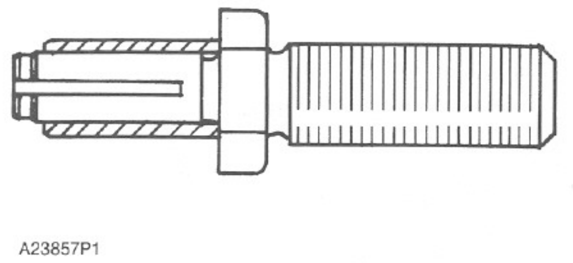


Location Of Bolt
(8) Washer. (9) Tachometer drive shaft.



Loosening Drive Gear
(10) 6V4069 Puller. (11) Bolts.

c. Put 6V4069 Puller (10) on the camshaft for the fuel injection pumps. Tighten bolts (11) until the drive gear on the camshaft for the fuel injection pumps comes loose.
d. Remove the 6V4069 Puller.
e. Turn the crankshaft COUNTERCLOCKWISE (as seen from rear of engine) until bolt (3) goes into the hole in the timing gear. With timing pin (2) in the notch in the camshaft for the fuel injection pumps, and bolt (3) in the hole in the timing gear, the timing for the engine is correct.
f. Install washer (8) and tachometer drive shaft (9). Tighten tachometer drive shaft to 149 ± 14 N•m (110 ± 10 lb ft). Remove timing pin (2).

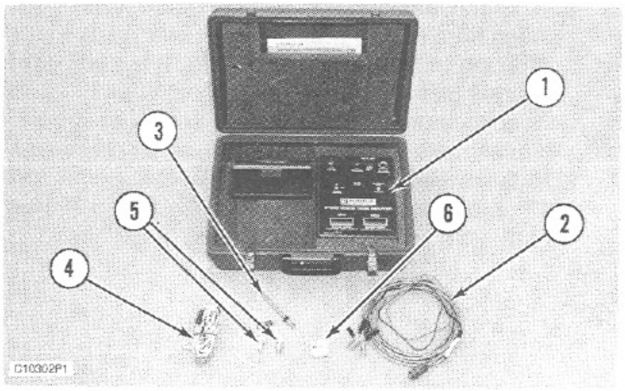


Tachometer Drive Shaft

g. Turn the crankshaft two complete revolutions COUNTERCLOCKWISE (as seen from rear of engine) and put timing pin (2) and bolt (3) in again. If timing pin (2) and bolt (3) can not be installed do Steps a through f again.
h. Remove bolt (3) from the timing gear and install in hole (5). Install the plug in timing hole (4). Remove timing pin (2) and install bolt (1). Install cover for the tachometer drive assembly (6).

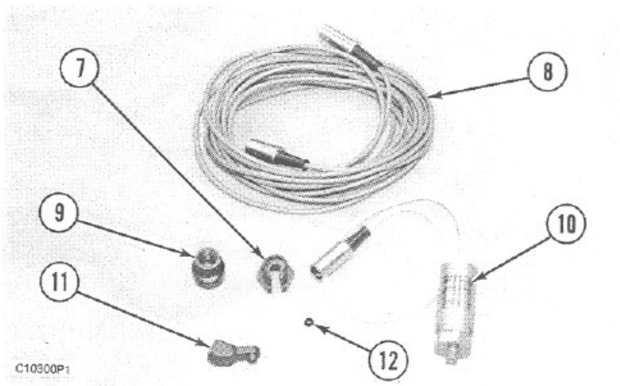
Checking Engine Timing And Automatic Timing Advance Unit With 8T5300 Timing Indicator Group And 8T5301 Diesel Timing Adapter Group

Tools Needed		
8T5300	Timing Indicator Group	1
8T5301	Diesel Timing Adapter Group	1



8T5300 Timing Indicator Group
(1) 8T5250 Engine Timing Indicator. (2) 5P7366 Cable Assembly. (3) 6V2197 Magnetic Transducer. (4) 5P7362 Cable. (5) 6V2199 & 6V3093 Transducer Adapters. (6) 8K4644 Fuse.

The 8T5300 Timing Indicator Group must be used with an 8T5301 Diesel Timing Adapter Group.



8T5301 Diesel Timing Adapter Group
(7) 5P7437 Adapter. (8) 6V2198 Cable. (9) 5P7436 Adapter. (10) 6V7910 Transducer. (11) 5P7435 Adapter. (12) 6V3016 Washer.

⚠ WARNING

A high pressure fuel line must be disconnected. To avoid personal injury or fire from fuel spray, the engine must be stopped before the fuel line is disconnected.

When checking the dynamic timing on an engine that has a mechanical advance, Caterpillar recommends that the serviceman calculate and plot the dynamic timing specifications first on a worksheet like Form No. SEHS8140. These worksheets are available in pads of 50 sheets, order one Form No. SEHS8140. See Special Instruction, Form No. SEHS8580 for information required to calculate the timing curve. For the correct timing specifications to use, see the Engine Information Plate for the performance specification number and make reference to the Fuel Setting And Related Information Fiche.

NOTE: For more information on acceptable tolerances for dynamic fuel injection timing, see Service Magazines dated 4-1-85 and 10-28-85.

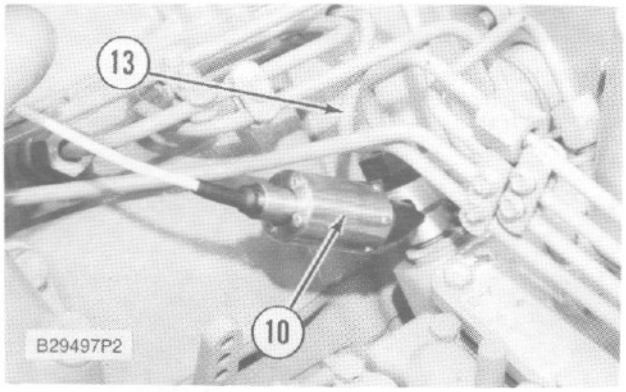
After the timing values are calculated and plotted, the dynamic timing should be checked with the 8T5300 Timing Indicator Group and the 8T5301 Diesel Timing Adapter Group. To do this, the serviceman must operate the engine from 1000 rpm (base rpm) to high idle and from high idle to 1000 rpm (base rpm). Unstable readings are often obtained below 1000 rpm. He must record the dynamic timing at each 100 rpm and at the specified speeds during both acceleration and deceleration. Then he should plot the results on the worksheet.

Inspection of the plotted values will show if the fuel injection timing is within specification and if it is advancing correctly.

1. Make reference to Special Instruction, Form No. SEHS8580 for complete service information and use of 8T5300 Timing Indicator Group.

2. Loosen all fuel line clamps that hold No. 1 fuel injection line and disconnect fuel injection line (13) for No. 1 cylinder at the fuel injection pump. Slide the nut up and out of the way. Put 5P7436 Adapter (9) in its place and turn adapter (9) onto the fuel pump bonnet until the top of the bonnet threads are approximately even with the bottom of the "window" in the adapter.

3. Put the 5P7435 Adapter (11) on 6V7910 Transducer (10) and put the end of the 5P7435 Adapter (11) in the "window" of the 5P7436 Adapter (9).

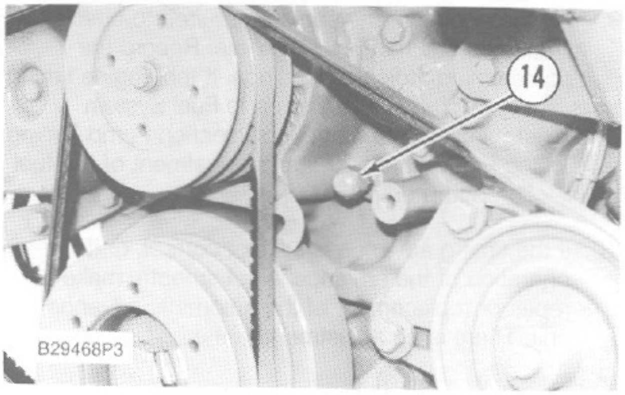


Transducer In Position
(10) Injection transducer. (13) Fuel injection line for No. 1 cylinder.

4. Put fuel injection line (13) on top of 5P7435 Adapter (11). Install 5P7437 Adapter (7) and tighten to 40 N•m (30 lb ft).

5. Remove fitting (14) from the front housing. Install transducer adapter (5) into hole fitting (14) was removed from. Tighten only a small amount.

6. Push the TDC magnetic transducer (3) into the transducer adapter (5) until it makes contact with the camshaft gear. Pull it back out 1.6 mm (.06 in) and lightly tighten the knurled locknut.

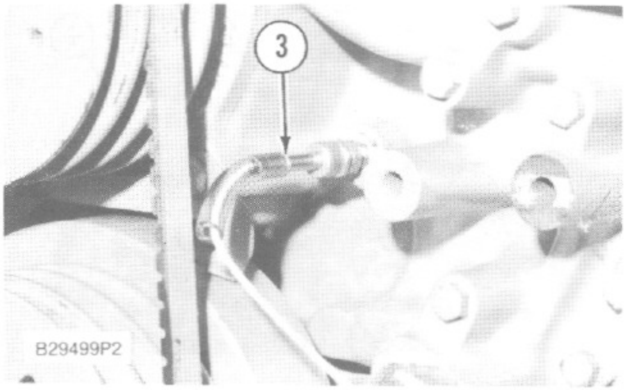


Location Of Fitting
(14) Fitting.

7. Connect the cables from the transducers to the Engine Timing Indicator. Make a calibration check of the indicator. For caon check of the indicator. For calibration procedure, make reference to Special Instruction, Form No. SEHS8580.

NOTICE

Be sure all test equipment cables are routed so they will not come into contact with the V-belts or other rotating components.



Transducer In Position
(3) TDC magnetic transducer.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

8. Start the engine and let it reach operating temperature. Then run the engine at approximately one-half throttle for eight to ten minutes before measuring timing.

9. Run the engine at the speeds required to check low idle, timing advance and high idle. Record the engine timing indicator readings. If the engine timing is not correct, make reference to Fuel System Adjustments: On Engine, Fuel Injection Pump Timing (Timing Pin Method) for static adjustment of the fuel injection pump drive.

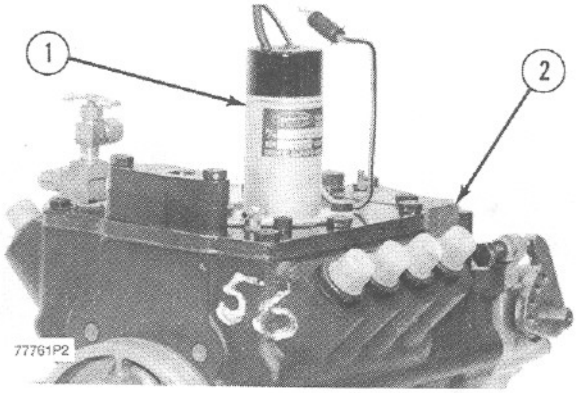
10. If the timing advance is still not correct, or if the operation of the advance is not smooth, make a repair or replacement of the automatic advance unit. There is no adjustment to the unit.

Fuel Setting

Tools Needed		
5P4203	Field Service Tool Group	1

The procedure that follows for fuel setting can be done with the housing for the fuel injection pumps either on or off the engine.

NOTE: If the fuel injection pump group is equipped with a fuel ratio control, the control must be removed before the fuel setting is checked or adjusted.



Removal Of Covers
(1) Shutoff solenoid. (2) Top cover.

NOTICE

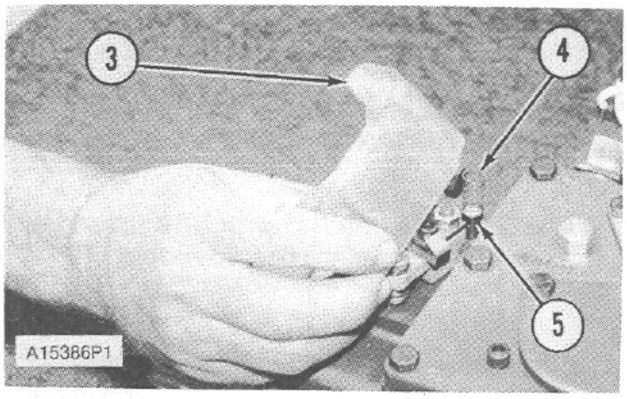
Before any service work is done on this fuel system, the outside of the housing for the fuel injection pumps and all parts connected to it must be especially clean.

---

1. Remove shutoff solenoid (1) and cover (2).

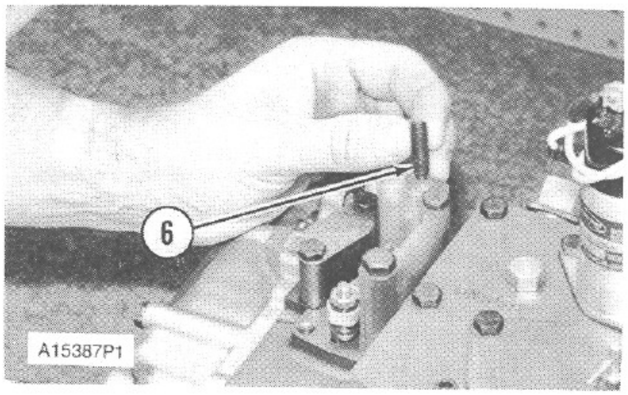
2. Put the 5P0298 Zero Set Pin (5), with 17.8507 on it, in the pump housing.

3. Put adapter (3) and spring (4) over zero set pin (5). Use a 1D4533 Bolt and a 1D4538 Bolt to fasten adapter (3) to the housing for the fuel injection pumps.



Installation Of Cover
(3) 5P6602 Adapter. (4) 3J6956 Spring. (5) 5P0298 Zero Set Pin, with 17.8507 on it.

4. Put screw (6) in the hole over pin (5) and spring (4).

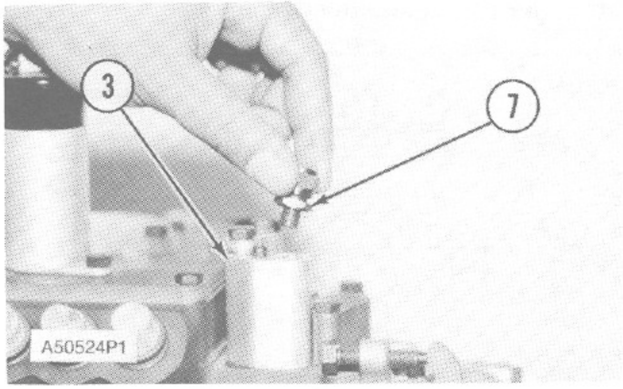


Installation Of Screw
(6) 8S7271 Screw.

5. Turn screw (6) clockwise until pin (5) is held against the housing for the fuel injection pump. DO NOT tighten screw (6) too tight.

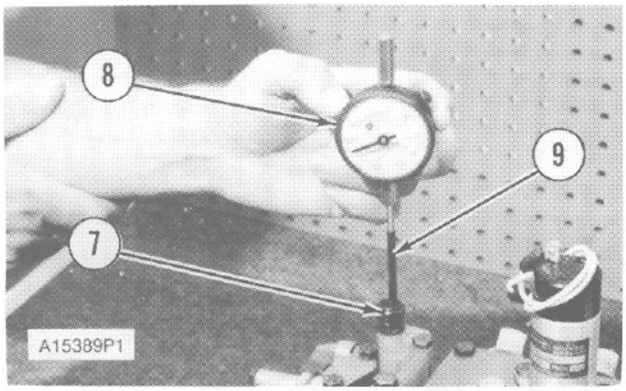
6. Put clamp (7) in adapter (3).

7. Move the governor control lever to FULL LOAD position.

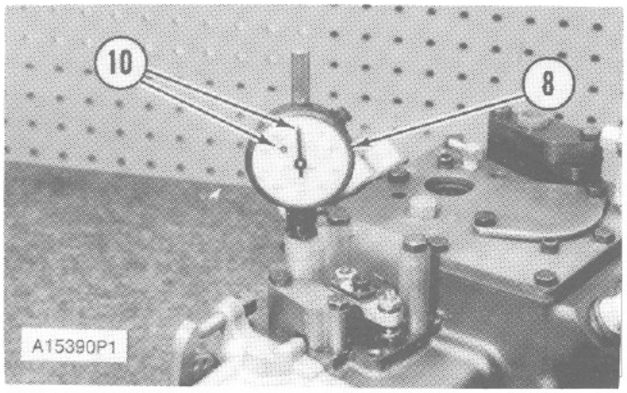


Installation Of Clamp
(3) Adapter. (7) 3P1565 Collet clamp.

8. Put 5P6531 Point (9) on dial indicator (8). Put the indicator assembly in clamp (7).



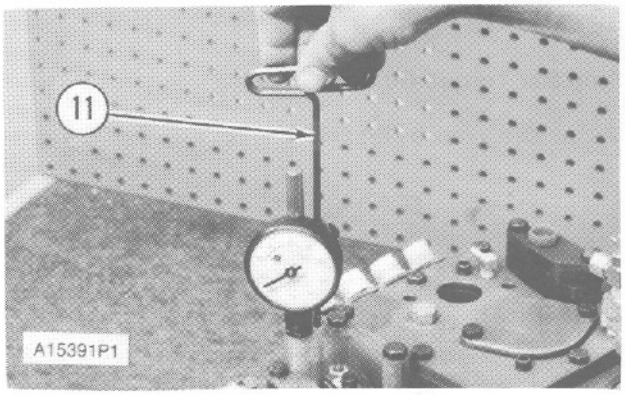
Installation Of Dial Indicator
(7) 3P1565 Collet Clamp. (8) 3P1567 Dial Indicator. (9) 5P6531 Contact Point, 57.2 mm (2.25 in) long.



Indicator Set On Zero
(8) 3P1567 Dial Indicator. (10) Pointers.

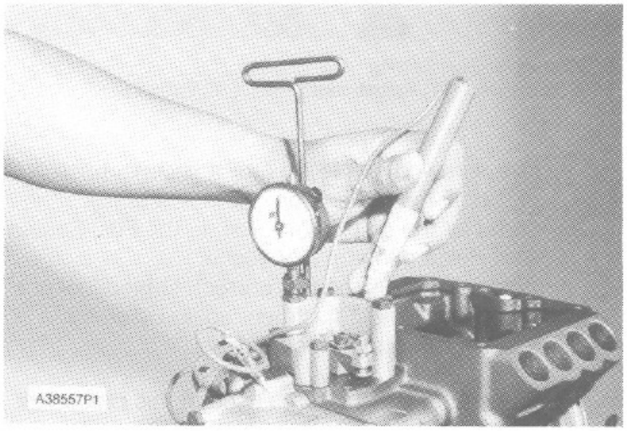
9. Adjust dial indicator (8) so both pointers (10) are on "0" (zero).

10. Use wrench (11) to turn the 8S7271 Screw (6) counterclockwise. Turn screw (6) six or more turns.



Loosening Screw (6)
(11) 5P4205 Wrench.

11. Put the clip end of the 8T0500 Circuit Tester to a good ground. Put the other end of the 8T0500 Circuit Tester on the load stop contact.



8T0500 Circuit Tester

12. Move the governor control lever to the LOW IDLE position.

13. Move the governor control lever slowly toward the HIGH IDLE position until the continuity light just comes on. Make a note of the reading on dial indicator (8). Do this step several times to make sure the reading is correct.

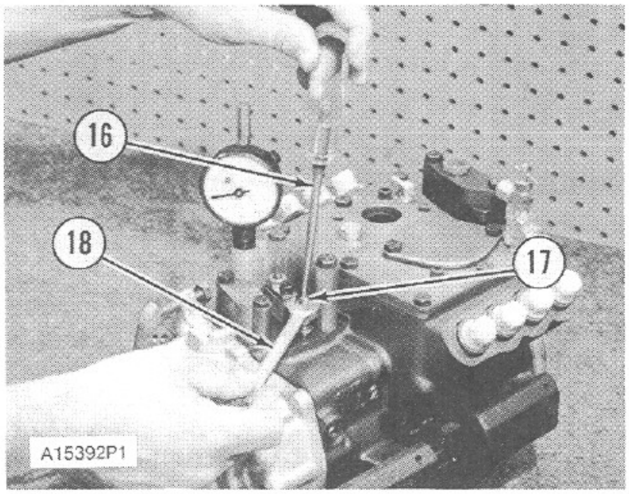
14. Make a comparison of this reading and the fuel setting in the Fuel Setting And Related Information Fiche.

15. If the reading on dial indicator (8) is not correct, do the fo the following.

Load Stop Adjustment

Stop Bar Torque Control Group

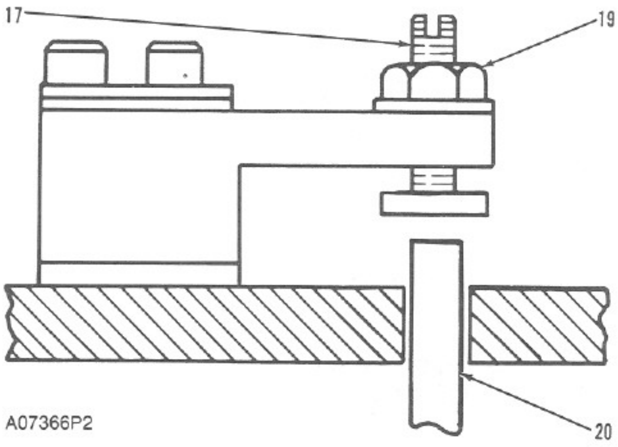
a. Use wrench (18) and locknut (19).



Adjustment Of Fuel Setting
(16) Screwdriver. (17) Adjustment screw. (18) Wrench.

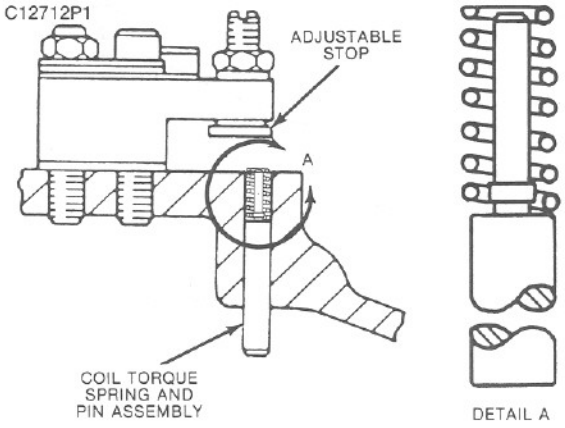
b. Use screwdriver (16) to turn adjustment screw (17) until the reading on dial indicator (8) is the same as the dimension given in the Fuel Setting And Related Information Fiche.
c. When the adjustment is correct, tighten locknut (19). Check the adjustment again by doing Steps 11 through 15 again.

NOTE: The same tools that are used in this procedure are also used for the fuel ratio control adjustment.



Adjustment Screw For Fuel Setting
(17) Adjustment screw. (19) Locknut. (20) Load stop pin.

Coil Type Torque Control Group



A coil type spring control group has been added to 3208 truck engines rated at 160 kW (215 hp) @ 2200 rpm. The new 4W9007 Pin Assembly (detail A) is a direct replacement for the load stop pin 4N0443 effective with Engine Serial No. 2Z34221. This new pin assembly can be adapted to 3208 truck engines 2Z13750 through 2Z34220, which have the above engine rating specifications.

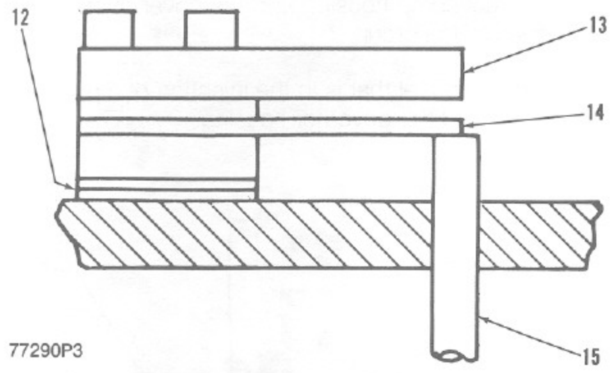
The coil type torque control group improves the torque rise as the engine lugs below full load rpm. The pin and spring assembly are matched and must be kept together.

Leaf Type Torque Spring

a. Write down the dimension that is on dial indicator (8).

b. Write down the dimension given in the Fuel Setting And Related Information Fiche.

c. Remove the test tools [adapter (3), spring (4), and dial indicator (8)] from the housing for fuel injection pumps.



Leaf Type Torque Spring
(12) Location of shims. (13) Stop bar. (14) Leaf type torque spring. (15) Load stop pin.

d. Install or remove shims at location (12) to get the correct dimension as given in the Fuel Setting And Related Information Fiche. The difference between the dimensions in (a) and (b) is the thickness and amount of shims to remove or install to get the correct setting.

e. Install the correct amount of shims (12) torque spring (14), and stop bar (13) on the housing for the fuel injection pumps.

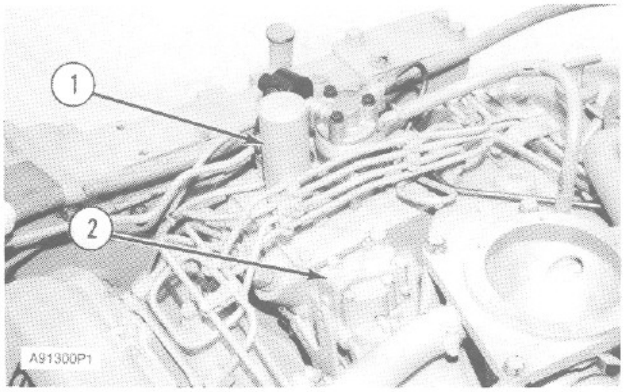
f. Install the test tools and do the test procedure again. Do this until the dimension on the dial indicator is the same as the dimension given in the Fuel Setting And Related Information Fiche. After the fuel setting is correct, remove the test tools. Install cover (2) and shutoff solenoid (1).

Fuel Ratio Control Adjustment

NOTE: The same tools are needed for the fuel ratio control adjustment that were used for the fuel setting. Make reference to Fuel Setting for the tools needed and instructions to install the tools.

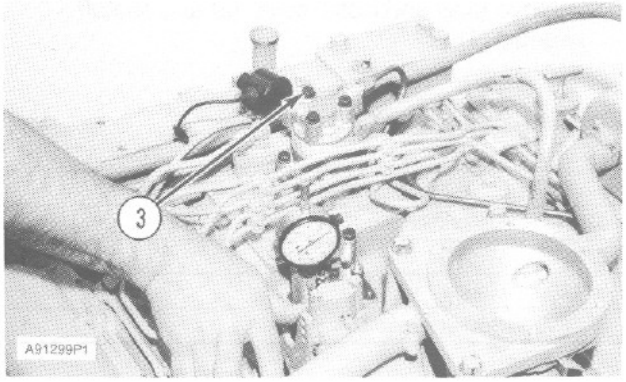
NOTE: The fuel setting must be correct before an adjustment is made to the fuel ratio control. Make reference to Fuel Setting.

1. Remove shutoff solenoid (1) and cover (2). Install tools and "zero" dial indicator as shown in Fuel Setting Steps 2 through10.



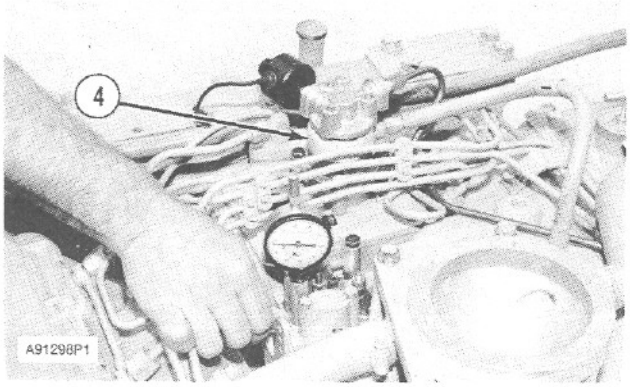
Removal Of Covers
(1) Shutoff solenoid. (2) Cover.

2. To check the fuel ratio control setting, move the governor lever slowly to the high idle position. Make a record of the reading on the dial indicator. Compare the reading with the specification given in the Fuel Setting And Related Information Fiche.



Checking Fuel Ratio Control Setting
(3) Bolts.

3. If an adjustment is needed, remove three bolts (3) from the fuel ratio control. Hold the governor lever in the high idle position and turn flange (4) until the fuel ratio control setting is correct.



Adjustment Of Fuel Ratio Control Setting
(4) Flange.

4. Move governor lever to low idle and again move the lever slowly to high idle to check the fuel ratio control setting.

5. Install bolts (3). Flange (4) can be turned a small amount to give alignment for bolts (3).

6. Remove tools and install cover (2) and shutoff solenoid (1).

Crossover Levers

Tools Needed		
3P1546	Calibration Pin	1
5P4206	Wrench	1
5P4209	Gauge	1
5P7253	Socket Assembly	1

Checking Crossover Levers

NOTE: The crossover levers normally do not need checking unless one or more of the following conditions exist (after the timing is checked and the other corrections shown in Troubleshooting have been made):

A. The engine produces too much black smoke.
B. The engine runs rough because fuel delivery is not even.
C. Some cylinders continue to fire at fuel shutoff position.
D. The complete injection group is being reconditioned.

NOTICE
Before any service work is done on this fuel system, the outside of the injection pump housing and all parts connected to it must be clean.

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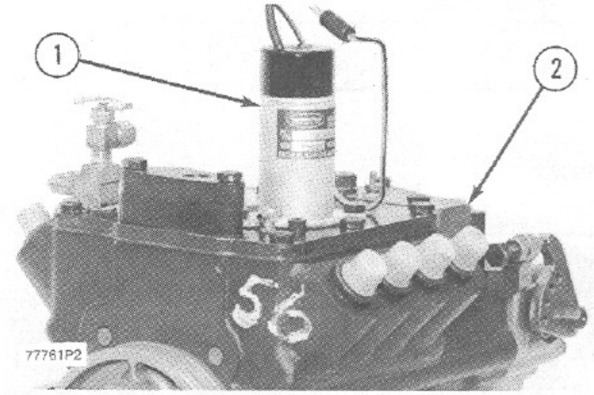
1. Remove the fuel shutoff solenoid (1), top cover (2) of the fuel pump housing and the cover over the torque control group.

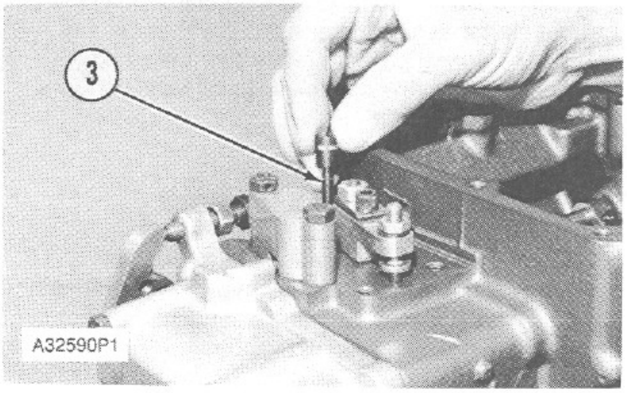
2. Remove the fuel that is in the injection pump housing and the governor housing.



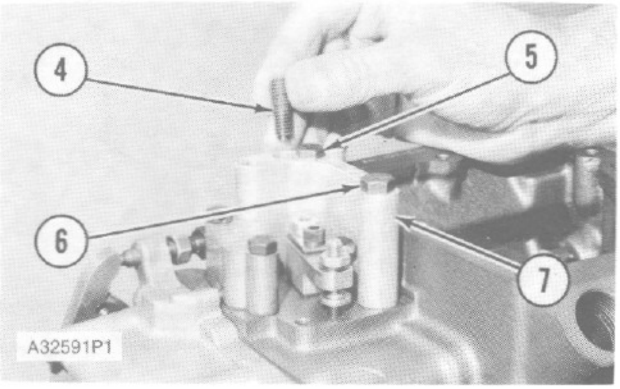
Removal Of Covers
(1) Shutoff solenoid. (2) Top cover.

3. Put the 3P1546 Calibration Pin (3) in calibration hole as shown.

4. Install the 5P6602 Adapter (7) as shown. Fasten it in position with a 1D4533 Bolt (5) and a 1D4538 Bolt (6).

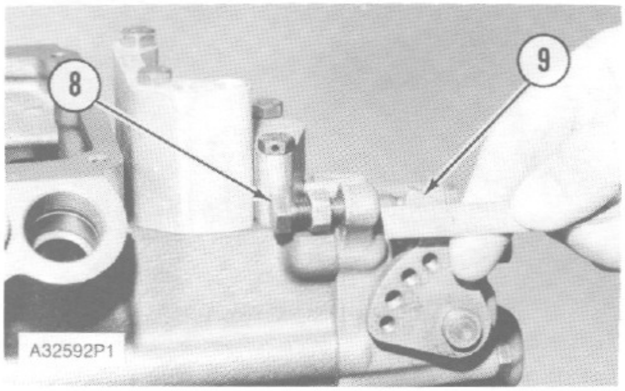


Installing Calibration Pin
(3) 3P1546 Calibration Pin with 15.9410 on it.



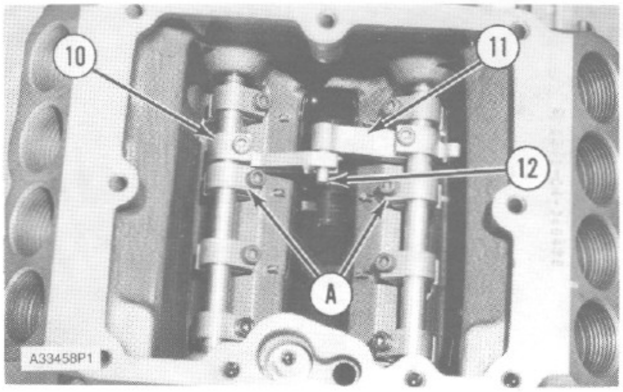
Installing 5P6602 Adapter And 8S7271 Screw
(4) Screw. (5) 1D4533 Bolt. (6) 1D4538 Bolt. (7) 5P6602 Adapter.

5. Put the 8S7271 Screw (4) (setscrew) in the hole over the calibration pin (3). Tighten the setscrew (4) to 2.3 to 2.8 N•m (20 to 25 lb in) with the 2P8264 Socket.



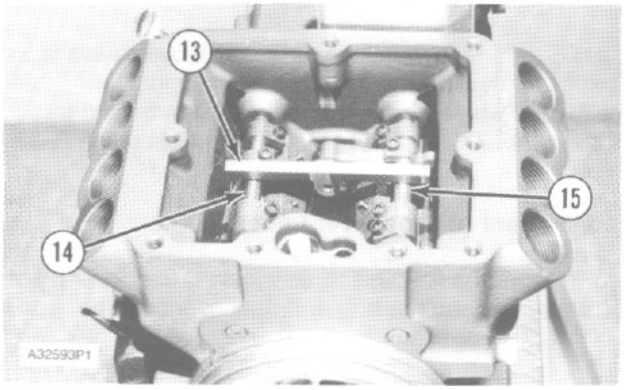
Adjustment Of Low Idle Screw
(8) Low idle screw. (9) Lever.

6. Adjust low idle screw (8) to position lever (9) to 8.9 ± 1.0 mm (.35 ± .04 in) from governor housing boss.



Crossover Levers
(10) Crossover lever. (11) Crossover lever. (12) Dowel pin.
(A) Sleeve levers.

7. Loosen the bolts that hold sleeve levers (A) and slide levers (A) out of the way.

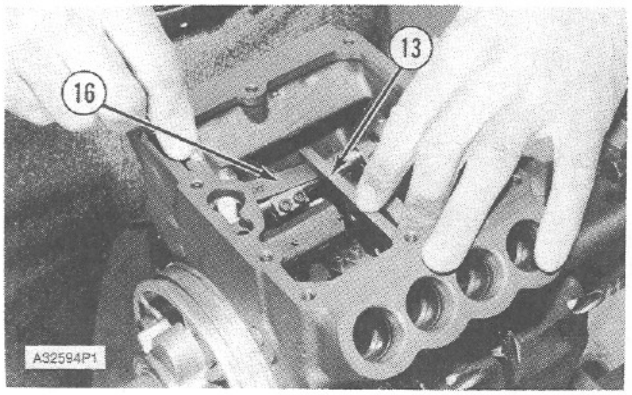


Installing 5P4209 Gauge
(13) 5P4209 Gauge. (14) Shaft. (15) Shaft.

8. Put gauge (13) on shafts (14) and (15). Slide gauge (13) toward crossover levers (10) and (11) until dowel pin (12) goes into hole in gauge (13).

9. If dowel pin (12) must be lifted to go into the hole in gauge (13), the levers must be adjusted. See Adjustment Of Crossover Levers.

10. If gauge (13) must be lifted more than 0.20 mm (.008 in) to let dowel pin (12) go into the hole in gauge (13), see Adjustment Of Crossover Levers.



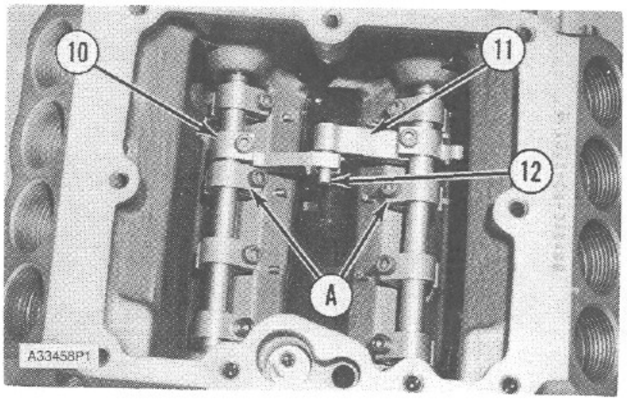
Checking Clearance Of Crossover Lever
(13) 5P4209 Gauge. (16) Feeler gauge.

11. To check the maximum clearance of 0.20 mm (.008 in) that is acceptable under one side of gauge (13), hold the center and one side of gauge (13) against sleeve lever shaft (15). Use a feeler gauge to check clearance.

NOTE: After the checking of the crossover levers is complete, the two fuel injection pumps must be calibrated where sleeve levers have been moved to install 5P4209 Gauge. See Fuel Pump Calibration.

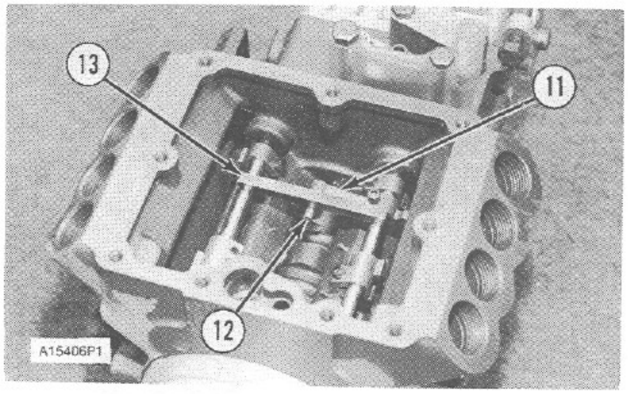
Adjustment of Crossover Levers

1. Remove the fuel shutoff solenoid (1) top cover (2) of the fuel pump housing and the cover over the torque control group.
2. Remove the fuel that is in the injection pump housing and the governor housing.
3. Put the 3P1546 Calibration Pin (3) in calibration hole.
4. Install the 5P6602 Adapter (7). Fasten it in position with a 1D4533 Bolt (5) and a 1D4538 Bolt (6).
5. Put the 8S7271 Screw (4) (setscrew) in the hole over the calibration pin (3). Tighten the setscrew (4) to 2.3 to 2.8 N•m (20 to 25 lb in) with the 2P8264 Socket.
6. Adjust low idle screw (8) to position lever (9) to 8.9 ± 1.0 mm (.35 ± .04 in) from governor housing boss.



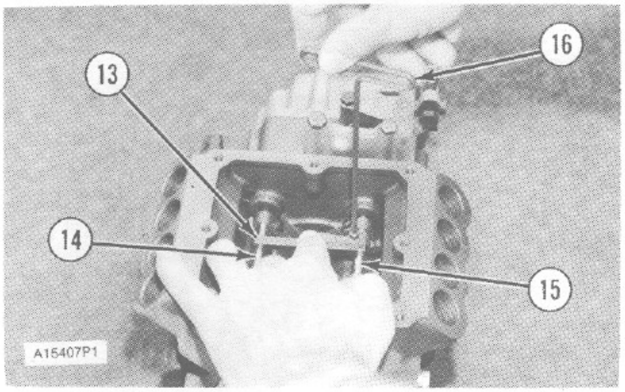
Crossover Levers
(10) Crossover lever. (11) Crossover lever. (12) Dowel pin.
(A) Sleeve levers.

7. Loosen the bolts that hold sleeve levers (A) and slide levers (A) out of the way.



5P4209 Gauge Installed
(11) Crossover lever. (12) Dowel pin. (13) 5P4209 Gauge.

8. Loosen the bolts that hold crossover lever (10) and (11) and move lever (10) off dowel pin (12).



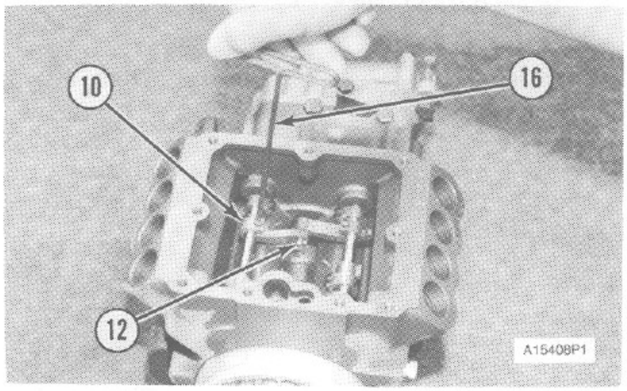
Adjustment Of Crossover Levers
(13) Gauge. (14) Shaft. (15) Shaft. (16) 5P4206 Wrench.

9. Put gauge (13) on shafts (14) and (15), put crossover lever (11) in a position so dowel pin (12) will fit in gauge hole. Hold gauge (13) down and torque the bolt that holds crossover lever (11) to 2.8 ± 0.2 N•m (24 ± 2 lb in).

10. Check adjustment again with the 5P4209 Gauge (13). Put gauge (13) on shafts (14) and (15), slide gauge toward crossover lever (11) to engage dowel pin (12) into hole in gauge (13).

11. If dowel pin (12) must be lifted to go into gauge, the lever must be adjusted again. If gauge (13) is lifted, a maximum of 0.20 mm (.008 in) clearance is acceptable under one side of gauge (13). Use a feeler gauge to check clearance.

12. Slide crossover lever (10) on to dowel pin (12). Torque the bolt that holds crossover lever (10) to 2.8 ± 0.2 N•m (24 ± 2 lb in).



Tightening Bolt
(10) Crossover lever. (12) Dowel pin. (16) Wrench.

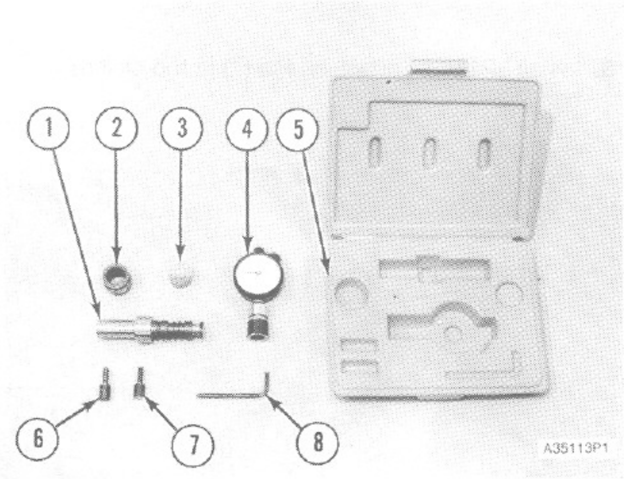
13. Check the adjustment again with the 5P4209 Gauge.

NOTE: After the adjustment of the crossover levers is completed, all of the fuel injection pumps must be calibrated. See Fuel Pump Calibration.

Fuel Pump Calibration

Tools Needed		
5P4203	Tool Group	1
8S2243	Wrench	1
5P6602	Adapter	1
5P4205	Wrench	1
1D4533	Bolt	1
1D4538	Bolt	1
8S7271	Screw	1
5P7253	Socket Assembly	1
5P4206	Wrench	1
6V0190	Clamp	1
3P2200	Sleeve Metering Calibration Tool Group	1

NOTE: 3P1540 Calibration pump must have the 5P6557 Spring installed instead of the 1P7377 Spring.



3P2200 Tool Group
(1) 3P1540 Calibration Pump. (2) 4N218 Bushing. (3) 1P7379 Microgauge. (4) 3P1568 Dial Indicator with 3P2226 Collet. (5) 5P6510 Box. (6) 3P1545 Calibration Pin with 17.3734 on it, (in-line engines). (7) 3P1546 Calibration Pin with 15.9410 on it. (Vee engines). (8) 1S9836 Wrench.

Checking Fuel Pump Calibration

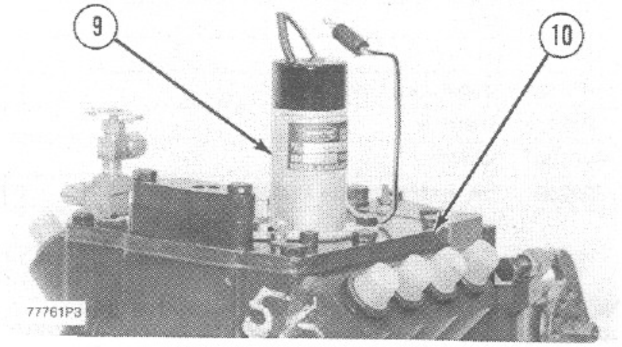
The following procedure for fuel pump calibration can be done with the housing for the fuel injection pumps on or off the engine.

NOTICE
Before any service work is done on this fuel system, the outside of the injection pump housing and all parts connected to it must be clean.

---

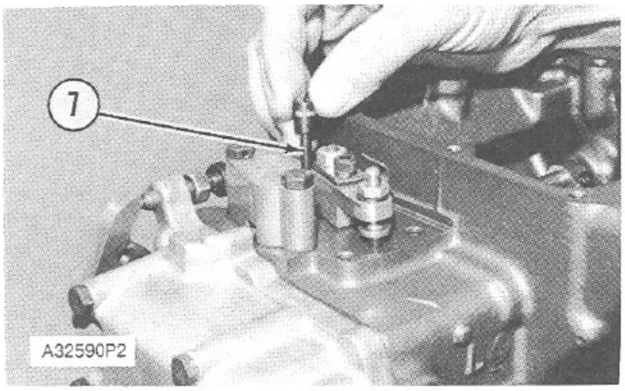
1. Remove the fuel shutoff solenoid (9), top cover (10) of the fuel pump housing and the cover over the torque control group.

2. Remove the fuel that is in the injection pump housing and the governor housing.



Removal Of Covers
(9) Shutoff solenoid. (10) Top cover.

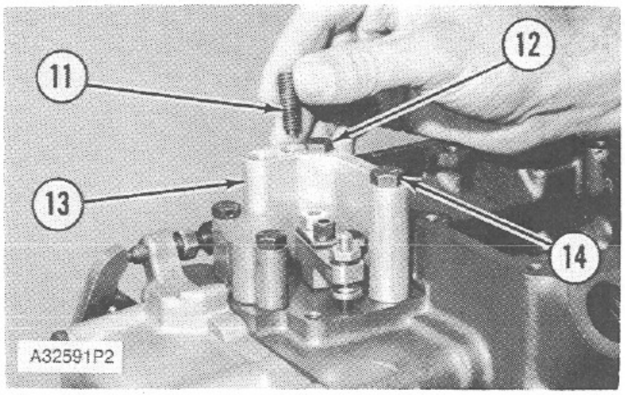
3. Install 3P1546 Calibration Pin (7) in the calibration hole.



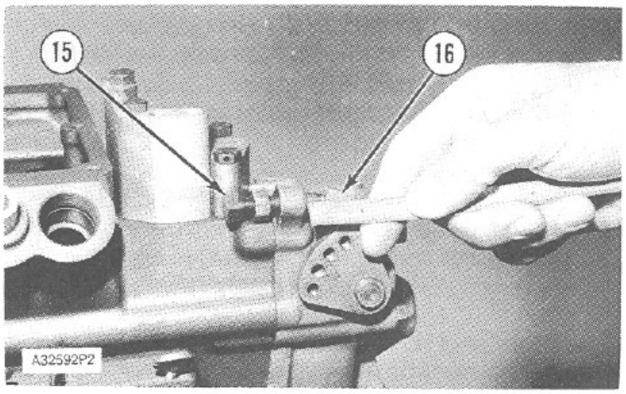
Installing Calibration Pin
(7) 3P1546 Calibration Pin with 15.9410 on it.

4. Install 5P6602 Adapter (13) as shown. Fasten it in position on the injection pump housing with a 1D4533 Bolt (12) and a 1D4538 Bolt (14).

5. Put 8S7271 Screw (11) in the hole over calibration pin (7). Tighten screw (11) to 2.3 to 2.8 N•m (20 to 25 lb in).



Installing 5P6602 Adapter And 8S7271 Screw
(11) Screw. (12) 1D4533 Bolt. (13) 5P6602 Adapter. (14) 1D4538 Bolt.



Adjustment Of Low Idle Screw
(15) Low idle screw. (16) Lever.

6. Adjust low idle screw (15) to position lever (16) to 8.9 ± 1.0 mm (.35 ± .04 in) from governor housing boss.

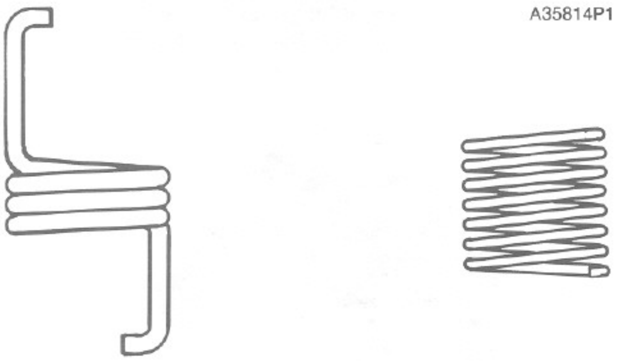
7. Use the 8S2243 Wrench and remove the fuel injection pumps to be checked.

NOTE: If pump is removed carefully, the sleeve will remain on the plunger. If the sleeve falls off the pump plunger during removal, find it immediately and replace it on the pump plunger before removal of another pump. The original sleeve must remain with the same pump plunger.

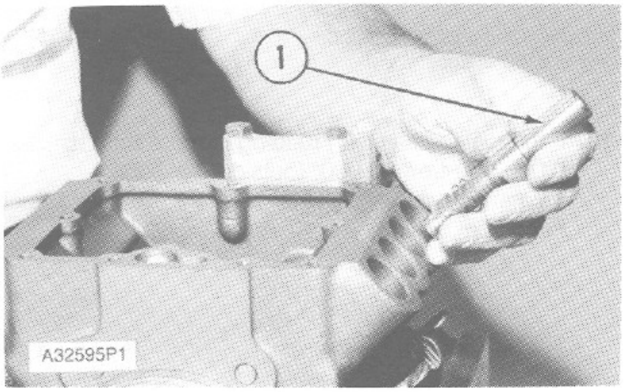
NOTE: When sleeve is installed on pump plunger, the narrower of the two lands on the sleeve must be toward top of pump (nearest the pump spring).

8. Clean the barrel and plunger of calibration pump (1). Put clean diesel fuel on the calibration pump for lubrication.

NOTE: Be sure that the spring on the calibration pump (1) is the 5P6557 Spring instead of the 1P7377 Spring which was installed on earlier calibration pumps.



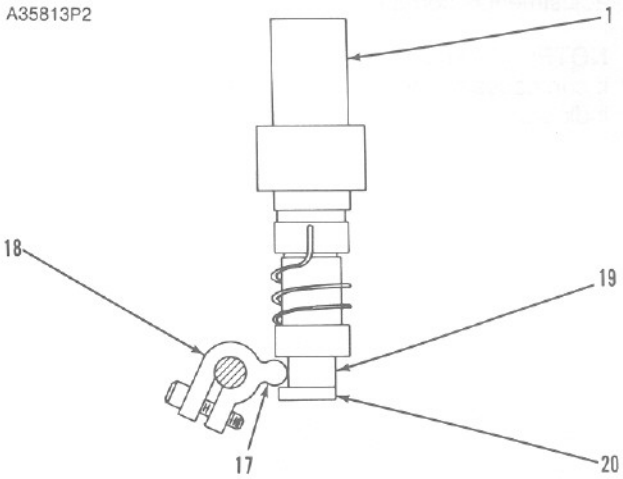
5P6557 Spring And 1P7377 Spring



Installing Calibration Pump
(1) 3P1540 Calibration Pump.

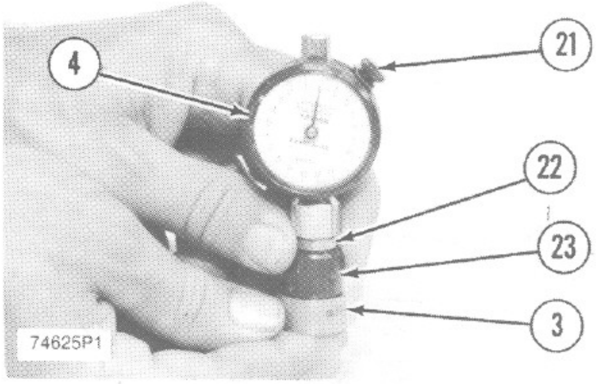
9. Put calibration pump (1) in the place of the pump to be checked with the flat place (20) on the plunger toward tang (17) on lever (18). When the calibration pump (1) is all the way in the bore, turn it 180° in either clockwise or counterclockwise direction. Tang (17) on lever (18) is now in groove (19) of calibration pump (1). Then install 4N218 Bushing (2). Use the 8S2243 Wrench and a torque wrench to tighten the bushing to 80 ± 7 N•m (60 ± 5 lb ft).

NOTE: Turning calibration pump (1) 180° gives the same reference point for all measurements.



Calibration Pump Installed
(1) 3P1540 Calibration Pump. (17) Tang on lever. (18) Lever.
(19) Groove of calibration pump. (20) Flat on plunger.

NOTE: Use 4N0218 Bushing (2) and calibration pump (1) together. The contact surfaces of the standard bushing, fuel injection pump and the housing for the fuel injection pumps are sealing surfaces. Keep them clean and free of scratches to prevent leaks.

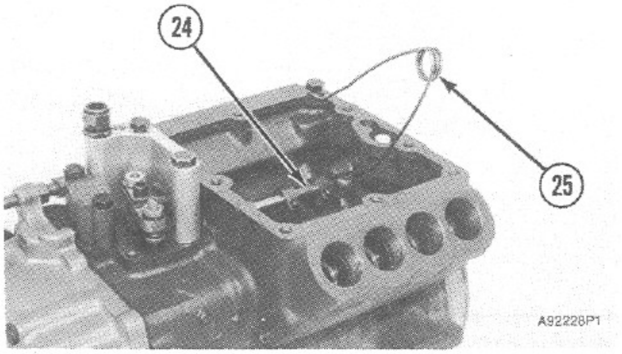


Putting Dial Indicator On Zero
(3) Microgauge. (4) 3P1568 Dial Indicator with 3P2226 Collet.
(21) Lockscrew. (22) Locknut. (23) 3P2226 Collet.

10. Put dial indicator (4) on microgauge (3) and hold them together tightly. Loosen lockscrew (21) and turn the face of dial indicator (4) to put the pointer at "0". Tighten lockscrew (21).

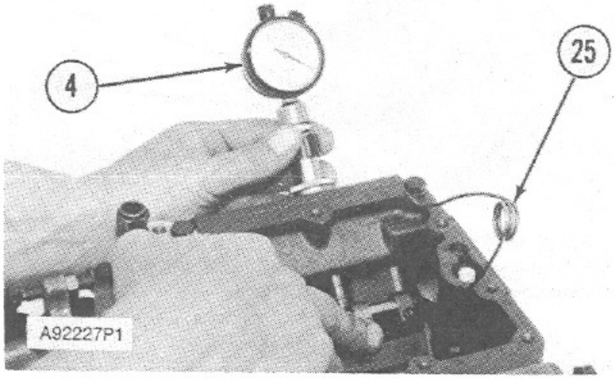
Remove dial indicator (4) from microgauge (3). Look at the face of dial indicator (4) and put dial indicator (4) on microgauge (3) again. The pointer must move through one to one and one half revolutions before stopping at exactly "0". If the number of revolutions is not correct, loosen the locknut on 3P2226 Collet (23), and adjust the position of the dial indicator until the adjustment is correct.

NOTE: If locknut (22) on the 3P2226 Collet is too tight, it can cause interference in the operation of the dial indicator.



6V0190 Clamp Installed
(24) Shaft. (25) 6V0190 Clamp.

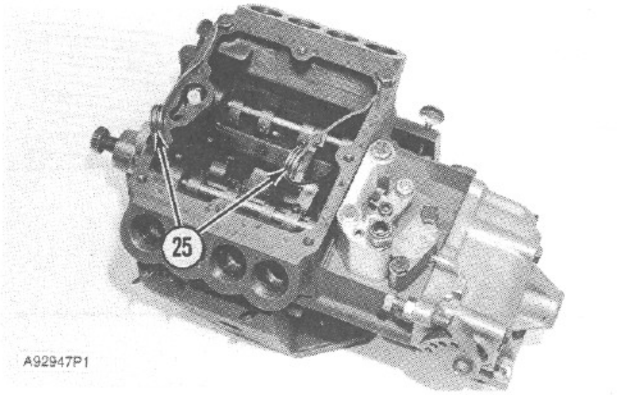
11. Put 6V0190 Clamp (25) in the position shown, next to the transfer pump end. Clamp (25) pushes shaft (24) down against the bottom of its bearing. The other end of shaft (24) is held down against its bearing by 3P1546 Calibration Pin (7) which is held by 8S7271 Screw (11). The combination of forces from clamp (25) and calibration pin (7) is necessary to hold shaft (24) is in its normal operating position against the lifting force from the spring in calibration pump (1).



Dial Indicator Position
(4) 3P1568 Dial Indicator with 3P2226 Collet. (25) Clamp.

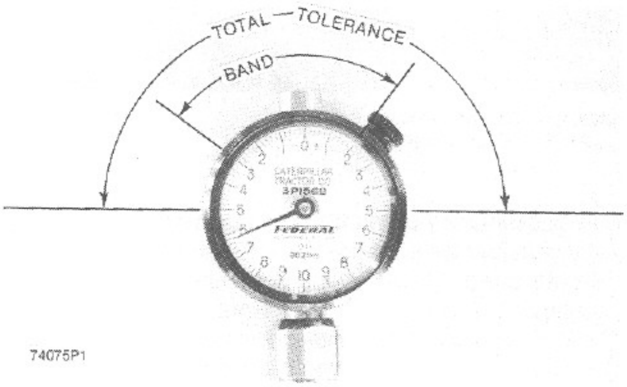
NOTE: When checking pumps on the "slave" side [side opposite from governor control lever (16)], put clamp (25) on both ends of sleeve shaft as shown.

12. Put dial indicator (4) on the calibration pump (1) as shown. Hold it tightly in place. Move shaft (24) toward the governor end to remove end play. To remove any clearance in the linkage, lift the crossover lever dowel and rapidly let it go. Do this several times. Then look at the reading on the dial indicator (4).



Installing Clamp On "Slave" Side
(25) 6V0190 Clamps.

13. If the dial indicator (4) reading is more than ± 0.050 mm from "0.000" (outside the Total Tolerance), do Steps 17 through 20, Adjusting Fuel Pump Calibration.



Dial Indicator Reading
Desired reading for all pumps is "0.000".

Maximum permissible tolerance for pump readings in any Fuel Injection Pump Group is 0.100 mm (-0.050 to +0.050 mm on dial indicator).

Maximum permissible differences between any two pumps in the same Fuel Injection Pump Group is 0.050 mm.

Total Tolerance shows the maximum permissible range of pointer positions which are acceptable. If any reading is outside the range of Total Tolerance, do Adjusting Fuel Pump Calibration for all pumps.

Band is an example only. It shows a 0.050 mm range. This range shows the maximum permissible difference between any two readings for all the pumps. If any two readings are farther apart than the 0.050 mm range, do Adjusting Fuel Pump Calibration for all pumps.

If the dial indicator (4) reading is near either end of the Total Tolerance, check another pump. If the next reading is outside the Total Tolerance or if the two readings have a difference of 0.050 mm or more, do the Steps 15 through 19, Adjustment Of Fuel Pump Calibration.

NOTE: The mechanic doing the checking must make the decisions of which and how many pumps to check according to the symptoms of the fuel injection pump being tested.

14. If dial indicator (4) readings for all the pumps are within the limits in Step 13, the calibration is acceptable. Remove the tooling, and install the parts which were removed.

NOTE: For troubleshooting purposes, if the dial indicator (4) reading is "0" or near "0", the calibration of the other pumps is probably in the tolerance.

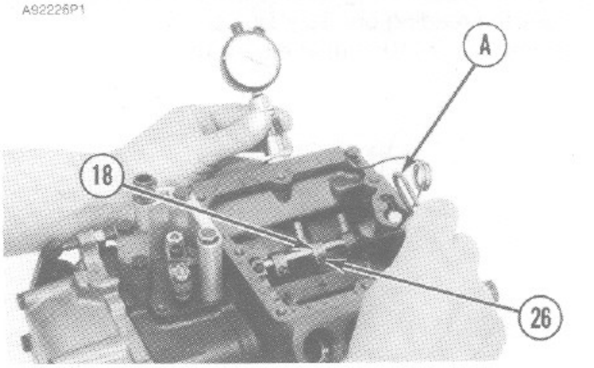
Adjustment of Fuel Pump Calibration

15. Remove all pumps with 8S2243 Wrench.

16. Clean the barrel and pump of calibration pump (1). Put clean diesel fuel on the calibration pump (1) for lubrication.

17. Install calibration pump (1) in the place of one of the pumps according to the procedure in Step 9.

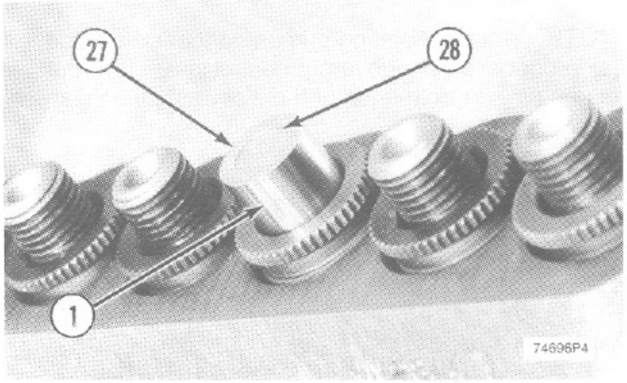
18. Loosen bolt (26) with 1S9836 Wrench (8) or 5P4206 Wrench. Turn the lever (18) on shaft (24) enough to move the top of plunger (28) of calibration pump (1) below top surface (27) of calibration pump (1). Tighten bolt (26) just enough for lever (18) to hold plunger (28) stationary.



5P4206 Wrench
(18) Lever. (26) Bolt. (A) 5P4206 Wrench.

NOTE: When bolt (26) has the correct torque, pushing with a small amount of force on lever (18) through the wrench moves plunger (28) in calibration pump (1).

19. Move shaft (24) toward the governor to remove end play. Then push down on lever (18) through the wrench until top of plunger (28) is almost even with top surface (27) of calibration pump (1) as shown.

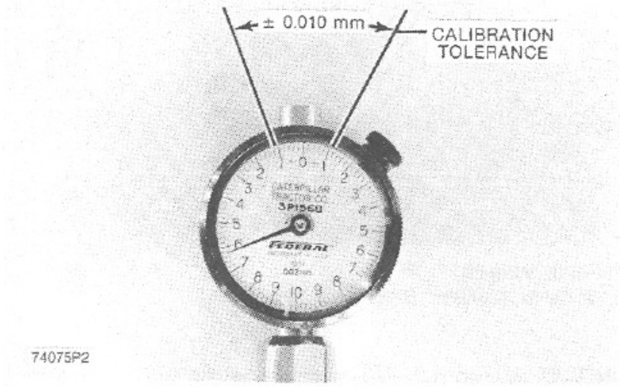


Plunger Position
(1) Calibration pump. (27) Top surface of calibration pump. (28) Plunger.

20. Check dial indicator (4) according to Step 10. Then put dial indicator (4) in place over the center of calibration pump (1) and hold it there tightly. Now move plunger (28) of calibration pump (1) by pushing on lever (18) through the wrench. Stop moving the plunger when the dial indicator is at approximately 0.009 mm past "0.000". Tighten bolt (26) to 2.8 ± 0.2 N•m (24 ± 2 lb in).

NOTE: When moving plunger (28), make sure that the last direction of plunger (28) movement is in the up direction. If plunger (28) goes up too far, move plunger (28) down to a position below that desired. Then move plunger (28) up to the desired position.

NOTE: The action of tightening bolt (26) usually changes the reading on dial indicator (4) by approximately (0.010 mm) in the minus direction.

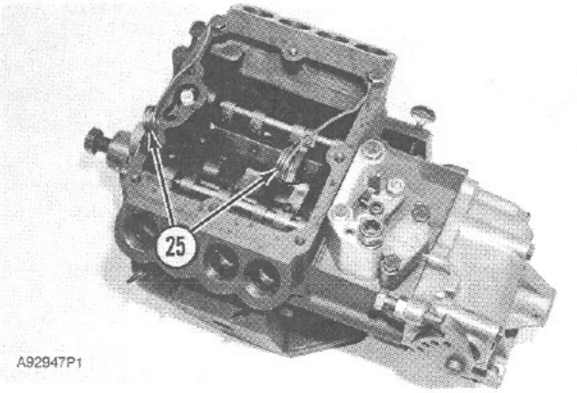


± 0.010 mm Calibration Tolerance

Move shaft (24) toward shutoff several times to remove clearance in the linkage. Dial indicator (4) reading must be (0.000 ± 0.010 mm) as shown.

When the pump calibration is correct make a record and then do the same procedure for all the other pumps.

NOTE: When calibrating pumps on the "slave" side [side opposite from governor control lever (16)], put clamp (25) on both ends of the sleeve shaft as shown.



Installing Clamp On "Slave" Side
(25) 6V0190 Clamps.

Governor Adjustments

NOTICE

A mechanic with training in governor adjustments is the only one to make the adjustment to the set point rpm.

Engine rpm must be checked with an accurate tachometer.

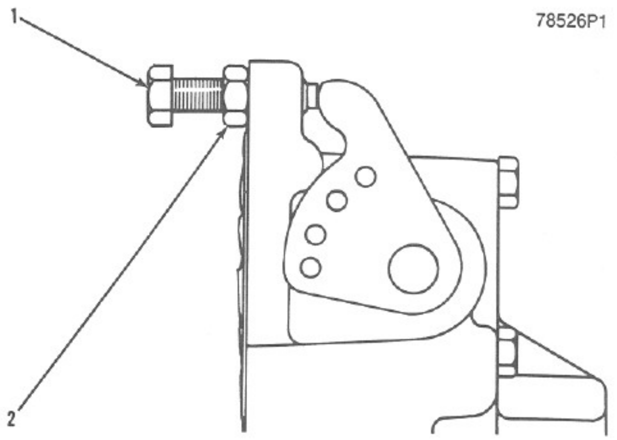
Low Idle Adjustment

NOTE: The correct LOW IDLE rpm is given in the Fuel Setting And Related Information Fiche.

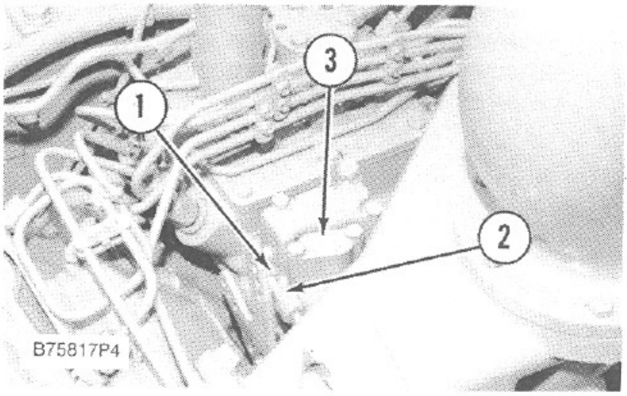
⚠ WARNING

To help prevent an accident caused by parts in rotation, work carefully around an engine that has been started.

Start the engine and run until the temperature of normal operation is reached. Check low idle rpm with no load on the engine. If an adjustment is necessary, use the procedure that follows:



Adjustment Of Low Idle RPM
(1) Adjustment bolt for low idle. (2) Locknut.



Adjustment Of Low Idle RPM
(1) Adjustment bolt for low idle. (2) Locknut. (3) Cover.

To adjust the LOW IDLE rpm, start the engine and run with the governor in the low idle position.

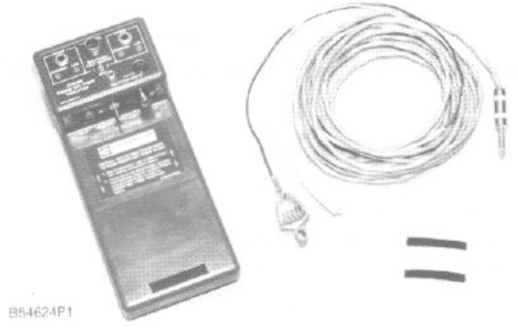
Loosen locknut (2) for low idle screw (1). Turn the low idle screw to get the correct low idle rpm. Increase engine speed and return to low idle and check low idle speed again. Tighten the locknut.

Checking Set Point (Balance Point)

The engine set point is an adjusted specification and is important to the correct operation of the engine. High idle rpm is NOT an adjusted specification. Set point (formerly balance point) is full load rpm plus an additional 20 rpm. Set point is the rpm at which the fuel setting adjustment screw and stop or first torque spring just start to make contact. At this rpm the fuel setting adjustment screw and stop or first torque spring still have movement between them. When additional load is put on the engine, the fuel setting adjustment screw and stop or first torque spring will become stable against each other. Set point is controlled by the fuel setting and the high idle adjustment screw.

There is a new and more accurate method for checking the "set point," formerly called the balance point, of the engine. If the tools for the new method are not available, there is an alternate method for checking the "set point."

Tools Needed		
6V4060	Engine Set Point Indicator Group	1



6V4060 Engine Set Point Indicator Group

The 6V4060 Engine Set Point Indicator Group with the 6V2100 Multitach can be used to check the set point. Special Instruction, Form No. SEHS7931 gives instructions for installation and use of this tool group.

Alternate Method

Tools Needed		
8T0500	Circuit Tester	1
6V3121	Multitach Group	1

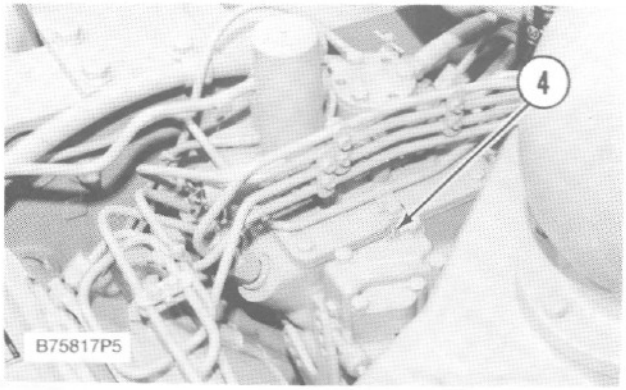
If the set point is correct and the high idle speed is within specifications, the fuel system operation of the engine is correct. The set point for the engine is:

A. At 20 rpm greater than full load speed.
B. The rpm where the fuel setting adjustment screw and stop or first torque spring just make contact.

Use the procedure that follows to check the set point. Make reference to Techniques For Loading Engines in Special Instruction, Form No. SEHS7050.

1. Connect a tachometer which has good accuracy to the tachometer drive.

2. Connect the clip end of the 8T0500 Circuit Tester to the brass terminal screw (4) on the governor housing. Connect the other end of the tester to a place on the fuel system which is a good ground connection.



Terminal Location
(4) Brass terminal screw.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

3. Start the engine.

4. With the engine at normal conditions for operation, run the engine at high idle.

5. Make a record of the speed of the engine at high idle.

6. Add load on the engine slowly until the circuit tester light just comes on (minimum light output). This is the set point.

7. Make a record of the speed (rpm) at the set point.

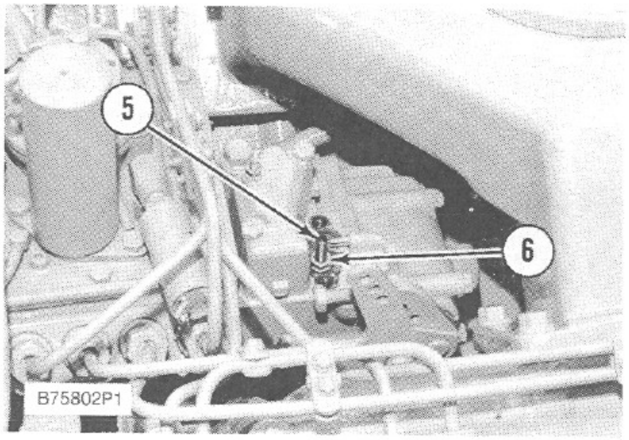
8. Repeat Step 6 several times to make sure that the reading is correct.

9. Stop the engine. Make a comparison of the records from Steps 5 and 7 with the information from the Engine Information Plate. If the Engine Information Plate is not available, see the Fuel Setting And Related Information Fiche. The tolerance for the set point is ± 10 rpm. The tolerance for the high idle rpm is ± 50 rpm. If the readings from Steps 5 and 7 are within the tolerance, no adjustment is needed.

NOTE: It is possible in some applications that the high idle rpm will be less than the lower limit. This can be caused by high parasitic loads such as hydraulic pumps, compressors, etc.

Adjusting Set Point (Balance Point)

1. If the set point and the high idle rpm are within tolerance, no adjustment is to be made.



Adjustment Of Set Point
(5) Adjustment screw. (6) Locknut.

2. If the set point rpm is not correct, remove cover (3) and loosen locknut (6). Turn adjustment screw (5) to adjust the set point to the mid point of the tolerance.

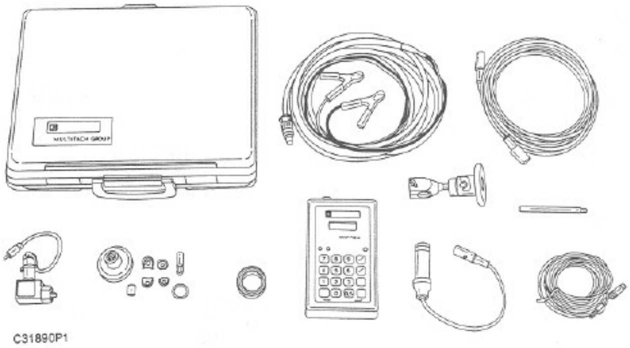
3. When the set point is correct, check the high idle rpm. The high idle rpm must not be more than the high limit of the tolerance.

If the high idle rpm is more than the high limit of the tolerance, check the governor spring and flyweights. If the high idle rpm is less than the low limit of the tolerance, check for excess parasitic loads and then the governor spring and flyweights.

Engine Speed Measurement

Tools Needed		
6V3121	Multitach Group or	1
6V4950	Injection Line Speed Pickup Group	1

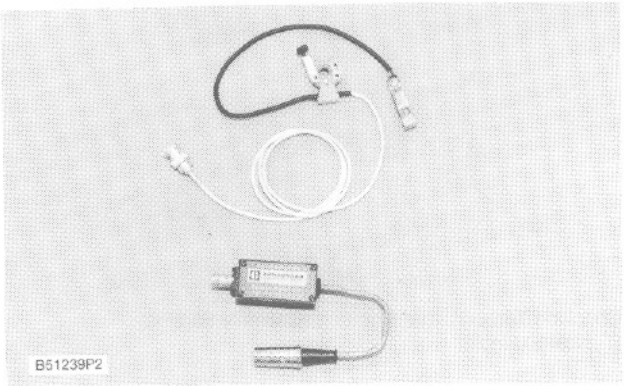
The 6V3121 Multitach Group can measure engine speed from a tachometer drive on the engine. It also has the ability to measure engine speed from visual engine parts in rotation.



6V3121 Multitach Group

Special Instruction, Form No. SEHS7807 is with the 6V3121 Multitach Group and gives instructions for the test procedure.

The 6V4950 Injection Line Speed Pickup Group is another diagnostic tool accessory that can be used with the 6V2100 Multitach. It can be used on all Caterpillar Diesel Engines equipped with 6 mm (.25 in) single wall fuel injection lines. With this pickup group, engine speed can be measured quickly, automatically and with an accuracy of ± 1 rpm.



6V4950 Injection Line Speed Pickup Group

Special Instruction, Form No. SEHS8029 is with the group and gives instructions for use of the 6V4950 Injection Line Speed Pickup Group.

Air Inlet And Exhaust System

Restriction Of Air Inlet And Exhaust

There will be a reduction of horsepower and efficiency of the engine if there is a restriction in the air inlet or exhaust system.

Air flow through the air cleaner must not have a restriction of more than 635 mm (25 in) of water difference in pressure.

Back pressure from the exhaust (pressure difference measurement between exhaust outlet elbow and atmosphere) must not be more than 686 mm (27 in) of water.

Measurement Of Pressure In Inlet Manifold

The efficiency of an engine can be checked by making a comparison of the pressure in the inlet manifold with the information given in the Fuel Setting And Related Information Fiche. This test is used when there is a decrease of horsepower from the engine, yet there is no real sign of a problem with the engine.

The correct pressure for the inlet manifold is given in the Fuel Setting And Related Information Fiche. Development of this information is done with these conditions:

a. 747 mm (29.4 in) of mercury barometric pressure.

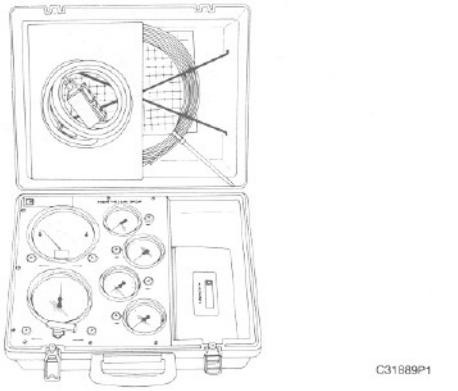
b. 229°C (85°F) outside air temperature.

c. 35 API rated fuel.

Any change fom these conditions can change the pressure in the inlet manifold. Outside air that has higher temperature and lower barometric pressure than given above will cause a lower horsepower and a lower inlet manifold pressure measurement than given in the Fuel Setting And Related Information Fiche. Outside air that has a lower temperature and a higher barometric pressure will cause higher horsepower and a higher inlet manifold pressure measurement.

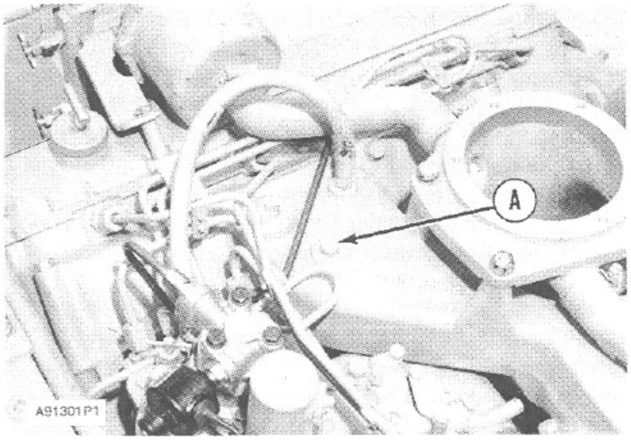
A difference in fuel rating will also change horsepower and the pressure in the inlet manifold. If the fuel is rated above 35 API, pressure in the inlet manifold can be less than given in the Fuel Setting And Related Information Fiche. If the fuel is rated below 35 API, the pressure in the inlet manifold can be more than given in the Fuel Setting And Related Information Fiche. Be Sure That The Air Inlet And Exhaust Do Not Have A Restriction When Making A check Of Pressure In The Inlet Manifold.

Use the 1U5470 Engine Pressure Group to check the pressure in the inlet manifold.

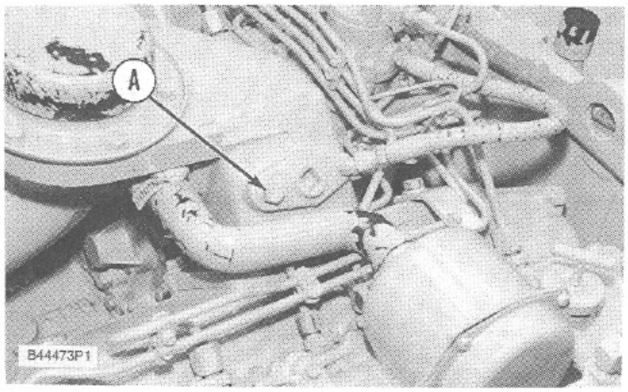


1U5470 Engine Pressure Group

This group has a gauge to read pressure in the inlet manifold. Special Instruction, Form No. SEHS8907 is with the tool group and gives information for its use.



Location For Pressure Test
(A) Remove fitting and install test fitting.



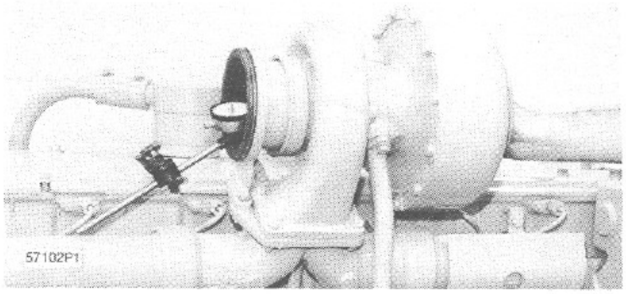
Location For Pressure Test
(A) Remove fitting and install test fitting.

Turbocharger

Every 7200 hours or if any unusual sound or vibration in the turbocharger is noticed, a quick check of bearing condition can be made without disassembling the turbocharger. This can be done by removing the piping from the turbocharger and inspecting the compressor impeller, turbine wheel and compressor cover. Rotate the compressor and turbine wheel assembly by hand and observe by feeling excessive end play. The rotating assembly should rotate freely with no rubbing or binding. If there is any indication of the impeller rubbing the compressor cover or the turbine wheel rubbing the turbine housing, recondition the turbocharger or replace with a new or rebuilt one.

End clearance is best checked with a dial indicator. Attach a dial indicator with the indicator point on the end of the shaft. Move the shaft from end to end making note of the total indicator reading.

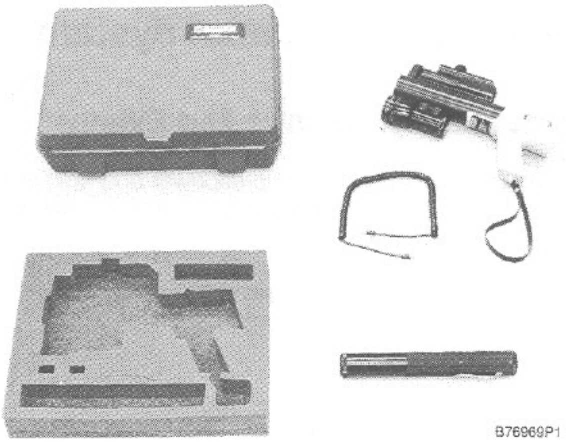
For the correct end play for the turbochargers see the Specifications Section. If end play is more than the maximum end play rebuild or replace the turbocharger. End play less than the minimum end play could indicate carbon build up on the turbine wheel and should be disassembled for cleaning and inspection.



Checking Turbocharger Rotating Assembly End Play
(Typical Example)

A more reliable check of bearing condition can be made only when the turbocharger is disassembled and the bearings, shaft journal and housing bore diameters can actually be measured.

Exhaust Temperature



6V5000 Infrared Thermometer Group

Use the 6V5000 Infrared Thermometer Group to check exhaust temperature. Special Instruction, Form No. SEHS8149 is with the tool group and gives instructions for the test procedure.

Air To Air Aftercooled Systems

Tools Needed		
FT1984	Air To Air Aftercooler Testing Group	1
FT1438	Dynamometer Testing Aftercooler	1

Visual Inspection

Inspect all air lines, hoses and gasket connections at each oil change. Make sure the constant torque hose clamps are tightened to the correct torque. Check the truck manufacturer's specifications for the correct torque. Check welded joints for cracks and make sure all brackets are tightened in position and are in good condition. Use compressed air to clean cooler core blockage caused by debris or dust. Inspect the cooler core fins for damage, debris or salt corrosion. Use a stainless steel brush with soap and water to remove corrosion.

⚠ WARNING

Pressure air can cause personal injury.

When using pressure air for cleaning, wear a protective face shield, protective clothing and protective shoes.

NOTE: When air to air aftercooler system parts are repaired and/or replaced, a leak test is recommended.

The use of winter fronts or shutters is discouraged with air to air aftercooled systems. Winter fronts can only be used on truck models where tests have shown that the engine jacket water will overheat before the inlet manifold air temperature is excessive. On these trucks, sensors and gauges or alarms are installed to indicate engine operating conditions before excessive inlet manifold air temperatures are reached. Check with the truck manufacturer on winter front and shutter application.

Air System Restriction

Pressure measurements should be taken at the turbocharger outlet and inlet manifold. When the total pressure drop of the charged air system at maximum air flow exceeds 13.5 kPa (4 in Hg), the air lines and cooler core must be inspected for internal restriction and cleaned, repaired or replaced as necessary.

Turbocharger Failure

⚠ WARNING

Pressure air can cause personal injury.

When using pressure air for cleaning, wear a protective face shield, protective clothing and protective shoes.

The maximum air pressure must be below 205 kPa (30 psi) for cleaning purposes.

If a turbocharger failure occurs, remove the air to air cooler core and flush internally with a solvent that removes oil and other foreign substances. Shake cooler to eliminate any trapped debris. Wash with hot, soapy water; rinse thoroughly with clean water; and blow dry with compressed air in reverse direction of normal air flow. Carefully inspect the system to make sure it is clean.

NOTICE

Do not use caustic cleaners or damage to the aftercooler core will result.

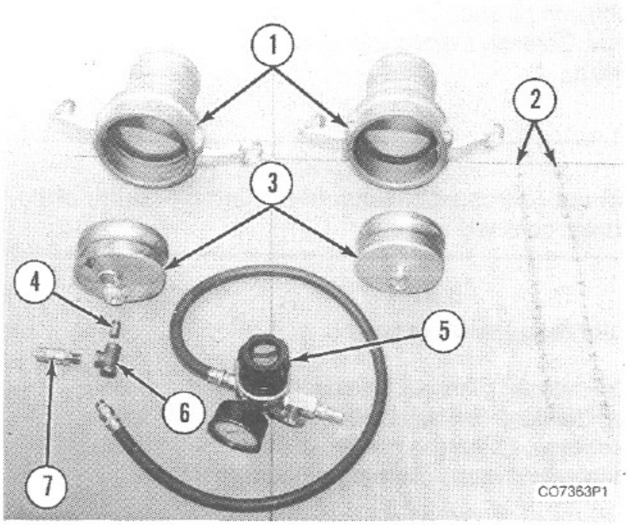
Inlet Manifold Pressure

Normal inlet manifold pressure with high exhaust temperature can be caused by cooler core fin blockage. Clean the cooler core fins, see Visual Inspection for the cleaning procedure to use.

Low inlet manifold pressure and high exhaust manifold temperatures can be caused by any of the conditions that follow:

1. A plugged air cleaner. Clean or replace the air cleaner as needed.
2. A blockage in the air lines between the air cleaner and turbocharger. All restrictions must be removed.
3. Cooler core leakage. Pressure test the cooler core, see Aftercooler Core Leakage for the correct procedure to use and repair or replace as needed.
4. Leakage from the pressure side of the induction system. Check and repair leaks.
5. Inlet manifold leak. Check for loose, missing and damaged fittings or plugs. Also check the manifold to cylinder head gaskets.

Aftercooler Core Leakage



FT1984 Air To Air Aftercooler Test Group
(1) Coupler. (2) Chain. (3) Dust plugs. (4) Nipple. (5) Regulator and valve assembly. (6) Tee. (7) Relief valve.

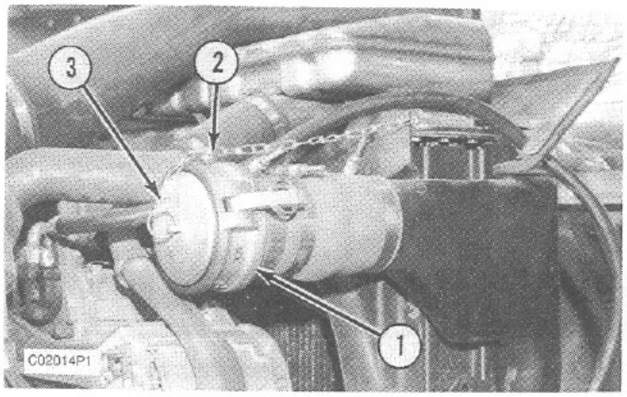
A low power problem in the engine can be the result of aftercooler leakage. Low power, low boost pressure, black smoke, and/or high exhaust temperature can be the result of an aftercooler system leakage.

NOTICE

Remove all air leaks from the system to prevent engine damage. In some operating conditions, the engine can pull a manifold vacuum for short periods of time. A leak in the aftercooler or air lines can let dirt and other foreign material into the engine and cause rapid wear and/or damage to engine parts.

A large cooler core leak often can be found by making a visual inspection. To check for smaller leaks, use the following procedure:

1. Disconnect the air pipes from the inlet and outlet side of the aftercooler core.

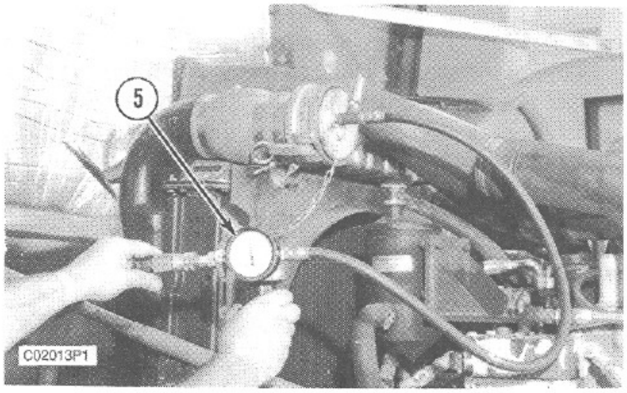


Tooling Installed
(1) Coupler. (2) Chain. (3) Dust plugs.

2. Install couplers (1) and dust plugs (3) from the FT1984 Air to Air Aftercooler Test Group as shown onn each side of the aftercooler core. Installation of additional hose clamps on hump hoes is recommended to prevent the hoses from bulging while the aftercooler core is being pressurized.

⚠ WARNING

Dust plug chains (2) must be installed to the aftercooler core or the radiator brackets to prevent possible injury while testing. Do not stand in front of the dust plugs while testing.



Pressurize System
(5) Regulator and valve assembly.

3. Install regulator and valve assembly (5) on the outlet side of the aftercooler. Attach air supply.

NOTICE

Do not use more than 240 kPa (35 psi) air pressure or damage to the aftercooler core can be the result.

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4. Open air valve and pressurize the aftercooler to 205 kPa (30 psi). Shut off air supply.

5. Inspect all connections for air leakage.

6. System pressure should not drop more than 35 kPa (5 psi) in 15 seconds.

7. If the pressure drop is more than specified, use a solution of soap and water to check all areas of possible leakage and look for air bubbles. Replace hoses or repair the aftercooler core as needed.

⚠ WARNING

To help prevent personal injury when the tooling is removed, relieve all pressure in the system slowly by using air regulator and valve assembly (5).

8. After testing, remove FT Tooling and connect air pipes on each side of the aftercooler.

Dynamometer Test

Air to air aftercooled chassis dynamometer tests, in hot ambient temperatures, can add a greater heat load to the jacket water cooling system, therefore the jacket water cooling system temperature must be monitored. Also, monitor the inlet air temperature as it may need a power correction factor along with fuel API, fuel temperature and barometric pressure.

For engine dynamometer tests, use the FT1438 Dynamometer Testing Aftercooler. FT1438 provides an air to water aftercooler to control the inlet air temperature to 43°C (110°F).

Cylinder Compression

An engine that runs rough can have a leak at the valves, or valves that need adjustment. Run the engine at the speed that gives rough running. To find a cylinder that has low compression or does not have good fuel ignition, loosen a fuel line nut at a fuel injection pump. This will stop the flow of fuel to that cylinder. Do this for each cylinder until a loosened fuel line is found that makes no difference in engine rough running. Be sure to tighten each fuel line nut after the test before the next fuel line nut is loosened. This test can also be an indication that the fuel injection is wrong, so more checking of the cylinder will be needed.

An analysis of the engine cylinder condition can be done with controlled pressure air through the cylinder head. Special Instruction, Form No. GMG00694 explains the procedure.

1. Remove the fuel injection nozzle.

2. Adapt an air hose to 1P5564 Adapter. Install the 1P5564 Adapter in the fuel injection nozzle opening in the cylinder head.

3. Start crankshaft rotation until the piston in the cylinder being inspected is at TC on the compression stroke. In this position, the valves of this cylinder will be against their seats.

4. Force the air into the cylinder and then check for air leakage. An air leak from the exhaust opening is an indication of exhaust valve leakage and an air leak from the air cleaner inlet is an indication of intake valve leakage. If the air leakage is into the crankcase during this test, the piston or piston rings can be the cause.

Valve Clearance Setting

Check and adjust the valve clearance with engine stopped.

Valve clearance is measured with a thickness gauge between the top of the valve stem and the rocker arm.

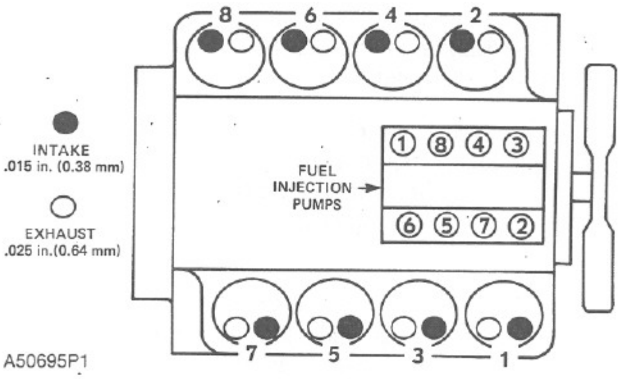
Valve Clearance Check: Engine Stopped
Exhaust ... 0.56 to 0.71 mm (.022 to .028 in) Intake ... 0.30 to 0.46 mm (.012 to .018 in)

NOTE: When the valve lash (clearance) is checked, adjustment is NOT NECESSARY if the measurement is in the range given in the chart for VALVE CLEARANCE CHECK: ENGINE STOPPED. If the measurement is outside this range, adjustment is necessary. See the chart for VALVE CLEARANCE SETTING: ENGINE STOPPED, and make the setting to the nominal (desired) specifications in this chart.

Valve Clearance Setting: Engine Stopped
Exhaust ... 0.64 mm (.025 in) Intake ... 0.38 mm (.015 in)

To check and make adjustment to the valve lash, use the procedure that follows:

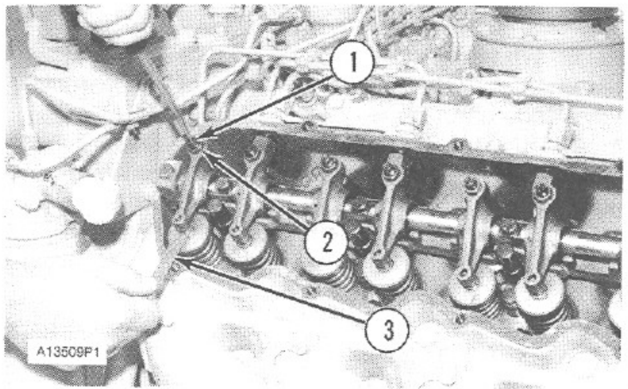
1. Remove the valve covers.



Cylinder, Valve And Pump Location

2. Turn the crankshaft COUNTERCLOCKWISE (as seen from rear of engine) until No. 1 piston is at top center on the compression stroke. The TDC-1 mark on the damper assembly will be in alignment with the timing pointer.

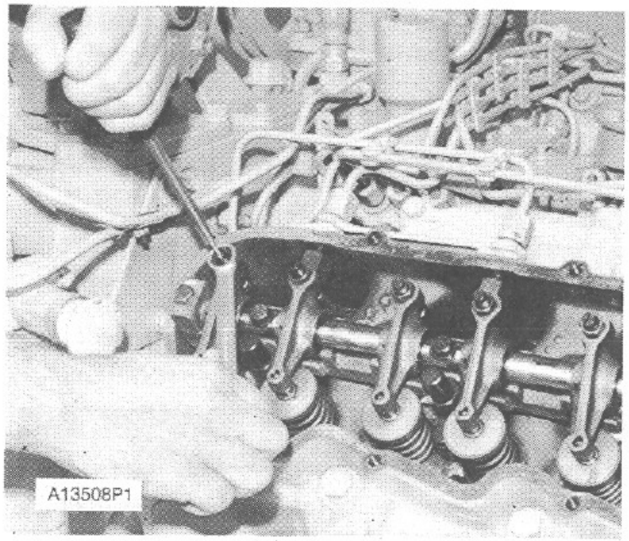
3. Make adjustment to the valves for No. 1 and No. 2 cylinders. To make the adjustment, loosen locknut (2). Turn the adjustment screw (1) until the feeler gauge (3) will go between the end of the valve stem and the rocker arm.



Valve Lash Adjustment
(1) Adjustment screw. (2) Locknut. (3) Feeler gauge.

4. After the adjustment is complete, hold adjustment screw (1) and tighten locknut (2) to 32 ± 7 N•m (24 ± 5 lb ft). After the locknut is tightened, check the adjustment again.

5. Turn the crankshaft 180° COUNTERCLOCKWISE (as seen from rear of engine). The VS mark on the damper assembly will be in alignment with the timing pointer. Make adjustment to the valves for No. 3 and No. 7 cylinders.



Tightening Locknut

6. Turn the crankshaft 180° COUNTERCLOCKWISE (as seen from rear of engine). The TDC-1 mark on the damper assembly will be in alignment with the timing pointer. Make adjustment to the valves for No. 4 and No. 5 cylinders.

7. Turn the crankshaft 180° COUNTERCLOCKWISE (as seen from rear of engine). The VS mark on damper assembly will be in alignment with the timing pointer. Make adjustment to the valves for No. 6 and No. 8 cylinders.

When the adjustment of the valve lash needs to be done several times in a short period of time, it can be an indication of wear in a different part of the engine. Find the problem and make any necessary repairs to prevent more damage to the engine.

Not enough valve lash, if not corrected, can be the cause of rapid wear of the camshaft and cam followers. Not enough valve lash can also be an indication of the seats for the valves being bad. Some reasons for the seats for the valves becoming bad are fuel injection nozzles with defects, restrictions to the inlet air or dirty air filters, wrong fuel setting, or using the engine on loads that are too large for the engine.

Too much valve lash, if not corrected, can be the cause for broken valve stems, push rods, or spring retainers. A fast increase in valve lash can be an indication of any of the following:

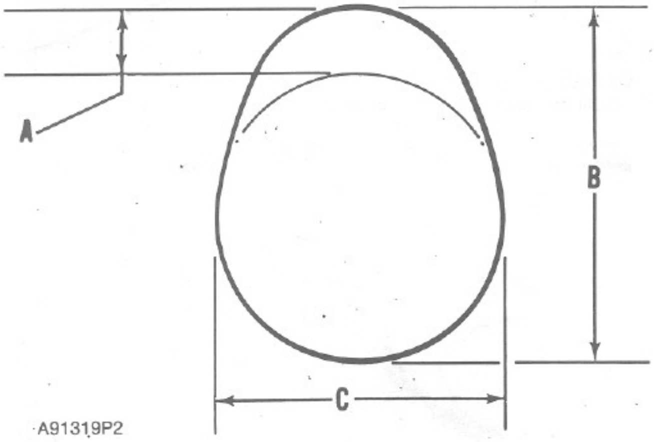
a. Camshaft and cam follower with wear.
b. Rocker arms with wear.
c. Push rods that are bent.
d. Loose adjustment screw for the valve lash.
e. Broken socket on the upper end of the push rod.

If the camshaft and cam followers show signs of rapid wear, look for fuel in the lubrication oil or dirty lubrication oil as a possible cause when making the necessary repairs.

Procedure For Measuring Camshaft Lobes

To find lobe lift (A) of camshaft, use the procedure that follows:

1. Measurement lobe height (B) of one exhaust and one intake lobe.
2. Measure base circle (C) of one exhaust and one intake lobe.
3. Subtract base circle (C) dimension (Step 2) from lobe height (B) dimension (Step 1). The difference is actual lobe lift (A).
4. The specified (new) lobe lift (A) is:



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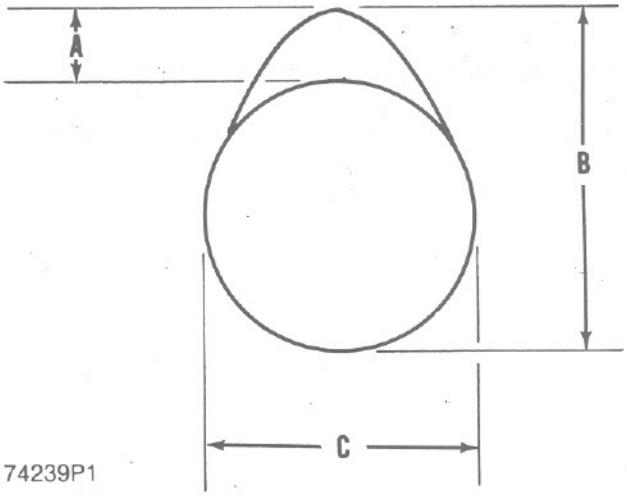
Camshaft Lobe (Roller Lifters)
(A) Lobe lift. (B) Lobe height. (C) Base circle.

Camshaft with Roller Lifters:

(a) Exhaust lobe	9.40 mm (.370 in)
(b) Intake lobe	9.33 mm (.367 in)



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Camshaft Lobe (Flat Face Lifters)
(A) Lobe lift. (B) Lobe height. (C) Base circle.

Camshaft with Flat Face Lifters:

(a) Exhaust lobe	9.40 mm (.370 in)
(b) Intake lobe	9.06 mm (.357 in)

5. The maximum permissible difference between actual lobe lift (Step 3) and specified lobe lift (Step 4) is 0.25 mm (.010 in).

Lubrication System

One of the problems in the following list will generally be an indication of a problem in the lubrication system for the engine.

Too Much Oil Consumption

Oil Pressure Is Low

Oil Pressure Is High

Too Much Bearing Wear

Increased Oil Temperature

Too Much Oil Consumption

Oil Leakage on Outside of Engine

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the oil pan gasket and all lubrication system connections. Check to see if oil is coming out of the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase, and this will cause gasket and seal leakage.

Oil Leakage Into Combustion Area Of Cylinders

Oil leakage into the combustion area of the cylinders can be the cause of blue smoke. There are four possible ways for oil leakage into the combustion area of the cylinders:

1. Oil leakage between worn valve guides and valve stems.
2. Worn or damaged piston rings or dirty oil return holes.
3. Compression ring not installed correctly.
4. Oil leakage past the seal rings in the impeller end of the turbocharger shaft.

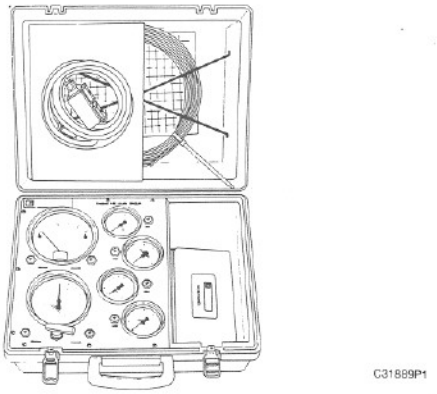
Too much oil consumption can also be the result of using oil with the wrong viscosity. Oil with a thin (low) viscosity can be caused from dirt or fuel getting in the crankcase, or by the engine getting too hot.

Measuring Engine Oil Pressure

Tools Needed		
1U5470	Engine Pressure Group	1

An oil pressure gauge that has a defect can give an indication of low oil pressure.

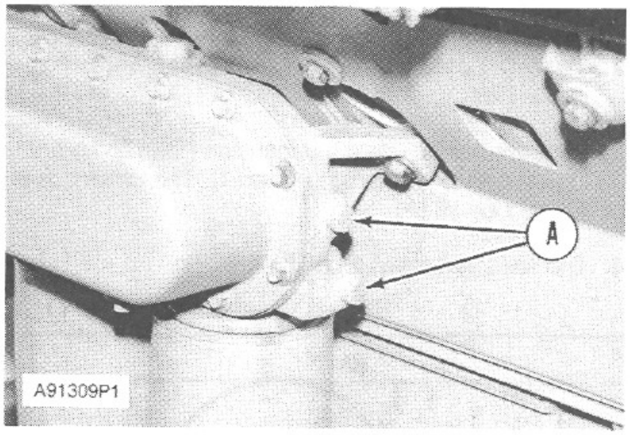
The 1U5470 Engine Pressure Group can be used to check engine oil pressure.



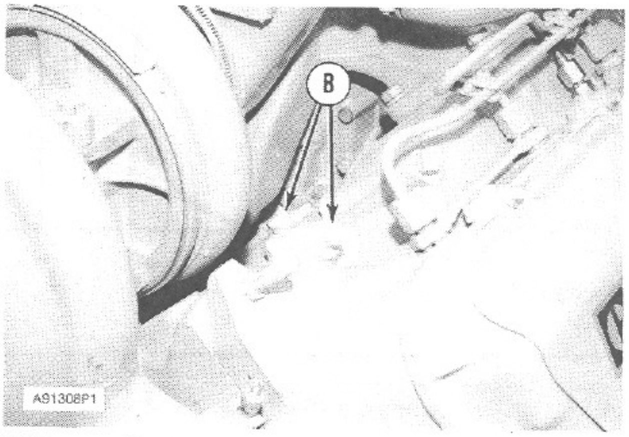
1U5470 Engine Pressure Group

This tool group has a gauge to read oil pressure in the engine. Special Instruction, Form No. SEHS8524 is with the tool group and gives instructions for the test procedure.

1. Be sure that the engine is filled to the correct level with SAE 10W30 oil. If any other viscosity of oil is used, the information in the Engine Oil Pressure Chart does not apply.
2. Connect the 1U5470 Engine Pressure Group to the main oil manifold at location (A) or location (B).



Oil Pressure Test Location
(A) Oil pressure test location at oil cooler.



Oil Pressure Test Location
(B) Oil pressure test location at rear of right cylinder head.

3. Run the engine to get the oil temperature at 93 ± 6°C (200 ± 10°F).
4. Keep the oil temperature constant with the engine at the rated rpm from the chart, and read the pressure gauge.

Engine Oil Pressure At 2800 RPM SAE 10W30 Oil at 93 ± 6°C (200 ± 10°F)	
Test Location	Pressure
A	380 to 550 kPa (55 to 80 psi)
B	345 to 520 kPa (50 to 75 psi)

If the results do not fall within the pressure range given in the chart, find the cause and correct it. Engine failure or a reduction in engine life can be the result if engine operation is continued with oil pressure outside this range.

Oil Pressure Is Low

Crankcase Oil Level

Check the level of the oil in the crankcase. Add oil if needed. It is possible for the oil level to be too far below the oil pump supply tube. This will result in the oil pump not having the ability to supply enough lubrication to the engine components.

Oil Pump Does Not Work Correctly

The inlet screen of the supply tube for the oil pump can have a restriction. This will result in cavitation and a loss of oil pressure. Air leakage in the supply side of the oil pump will also cause cavitation and loss of oil pressure. If the pressure regulating valve for the system is held in the open (unseated) position, the lubrication system can not get to maximum pressure. Oil pump gears that have too much wear will cause a reduction in oil pressure.

Oil Filter and Oil Cooler

A dirty oil filter will cause a reduction in oil pressure. When the oil filter is filled with dirt, a restriction of oil flow through the filter and a reduction of filtered oil pressure is the result.

The bypass valve will cause the flow of oil to go around the filter elements when there is a reduction to the flow through the elements. When the bypass valve is open, oil that is not filtered is permitted to flow through the engine. To correct this problem, install a new Caterpillar filter.

Look for a restriction in the oil passages of the oil cooler. If the oil cooler has a restriction, the oil cooler bypass valve in the oil filter base will open. This will cause the flow of oil to go around the oil cooler. The oil temperature will be higher than normal when the engine is running. The oil pressure of the engine will become low if the oil cooler has a restriction.

Too Much Clearance at Engine Bearings or Open, Broken or Disconnected Oil Line or Passage in Lubrication System

Components that are worn and have too much bearing clearance can cause oil pressure to be low. Low oil pressure can also be caused by an oil line or oil passage that is open, broken or disconnected.

Oil Pressure Is High

Oil pressure will be high if the bypass valve for the oil pump can not move from the closed position.

Too Much Bearing Wear

When some components of the engine show bearing wear in a short time, the cause can be a restriction in the oil passage. A broken oil passage can also be the cause.

If the gauge for oil pressure shows the correct oil pressure, but a component is worn because it is not getting enough lubrication, look at the passage for oil supply to that component. A restriction in a supply passage will not let enough lubrication get to a component and this will cause early wear.

Increased Oil Temperature

Look for a restriction in the oil passages of the oil cooler. If the oil cooler has a restriction, the oil temperature will be higher than normal when the engine is operated. The oil pressure of the engine will not get low just because the oil cooler has a restriction.

Also check the oil cooler bypass valve to see if it is held in the open position (unseated). This condition will let the oil through the valve instead of the oil cooler, and oil temperature will increase.

Cooling System

The cooling system is a pressure type with regulators at the outlet, the cooling system is equipped with a shunt line.

A pressure type cooling system gives two advantages. The first advantage is that the cooling system can have safe operation at a temperature that is higher than the normal boiling (steam) point of water. The second advantage is that this type system prevents cavitation (low pressure bubbles suddenly made in liquids by mechanical forces) in the water pump. With this type system, it is more difficult for an air or steam pocket to be made in the cooling system.

The cause for increased engine temperature is generally because regular inspections of the cooling system were not made. Make a visual inspection of the cooling system before a test is made with test equipment.

Visual Inspection Of The Cooling System

1. Check coolant level in the cooling system.
2. Look for leaks in the system.
3. Look for bent radiator fins. Be sure that air flow through the radiator does not have a restriction.
4. Inspect the drive belt for the fan.
5. Check for damage to the fan blades.
6. Look for air or combustion gas in the cooling system.
7. Inspect the pressure cap and the sealing surface for the cap. The sealing surface must be clean.

Testing The Cooling System

Remember than temperature and pressure work together. When making a diagnosis of a cooling system problem, temperature and pressure must both be checked. Cooling system pressure will have an effect on cooling system temperatures. For an example, look at the chart to see the effect of pressure and height above sea level on the boiling (steam) point of water.

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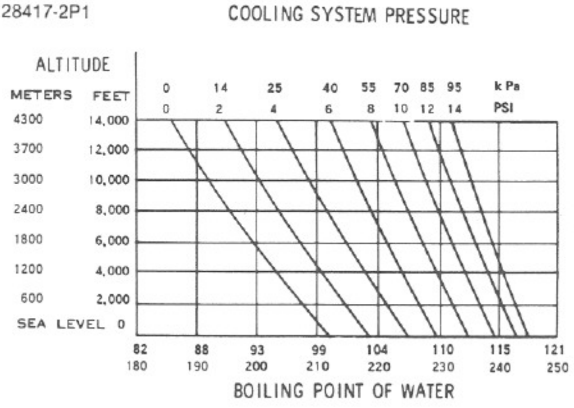
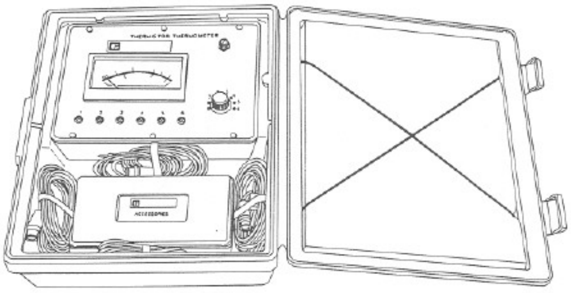


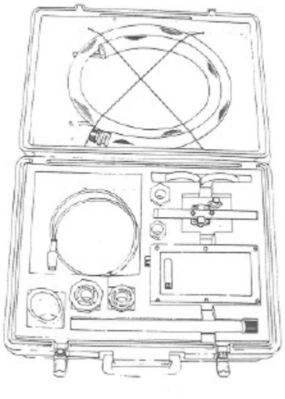
Tools Needed		
8T0470	Thermistor Thermometer Group	1
8T2700	8T2700 Blowby/Air Flow Indicator Group	1
6V3121	6V3121 Multitach Group	1
9S8140	Cooling System Pressurizing Pump Group	1

The 8T0470 Thermistor Thermometer Group is used in the diagnosis of overheating (engine hotter than normal) or overcooling (engine cooler than normal) problems. This group can be used to check temperatures in several different parts of the cooling system. The testing procedure is in Special Instruction, Form No. SEHS8446.



8T0470 Thermistor Thermometer Group

The 8T2700 Blowby/Air Flow Indicator Group is used to check the air flow through the radiator core. The test procedure is in Special Instruction, Form No. SEHS8712.



8T2700 Blowby/Air Flow Indicator Group

The 6V3121 Multitach Group is used to check the fan speed. The testing procedure is in Special Instruction, Form No. SEHS7807.

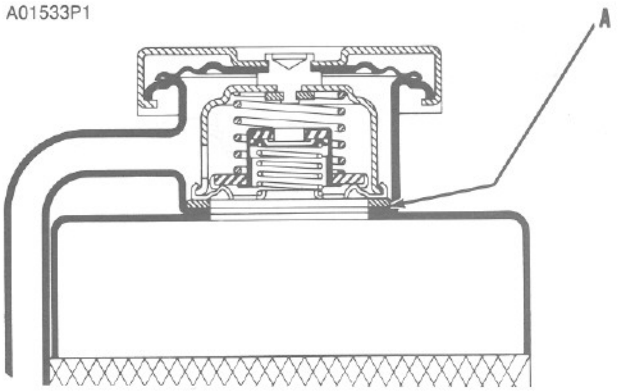
6V3121 Multitach Group

Pressure Cap Test

Tools Needed		
9S8140	Cooling System Pressurizing Pump Group	1

One cause for a pressure loss in the cooling system can be a bad seal on the pressure cap of the system. Inspect the pressure cap carefully. Look for damage to the seal or to the surface that seals. Any foreign material or deposits on the cap, valve, seal or surface that seals must be removed.

The 9S8140 Cooling System Pressurizing Pump Group is used to test pressure caps and to pressure check the cooling system for leaks.



Typical Schematic Of Pressure Cap
(A) Sealing surface of cap and radiator.

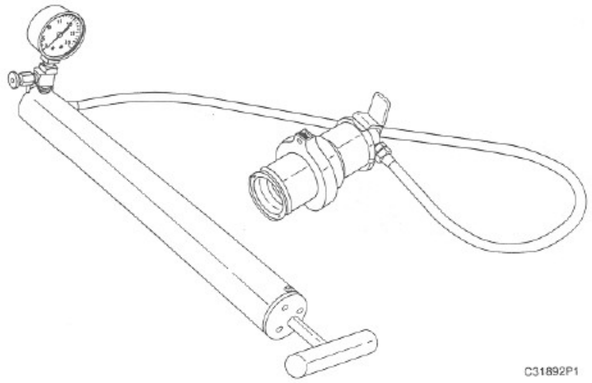
To check the pressure cap for the pressure that makes the pressure cap open, use the procedure that follows.

⚠ WARNING

DO NOT loosen the filler or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.

1. After the engine is cool, loosen the pressure cap to the first stop and let the pressure out of the cooling system. Then remove the pressure cap.

2. Put the pressure cap on the 9S8140 Cooling System Pressurizing Pump Group.



9S8140 Cooling System Pressurizing Pump Group

3. Look at the gauge for the exact pressure that makes the pressure cap open.

4. Make a comparison of the reading on the gauge with the correct pressure at which the pressure cap must open.

NOTE: The correct pressure that makes the pressure cap open is on the pressure cap and is also in the Specifications.

5. If the pressure cap is bad, install a new pressure cap.

Radiator and Cooling System Leak Tests (Systems That Use Pressure Cap)

To test the radiator and cooling system for leaks, use the procedure that follows:

⚠ WARNING

DO NOT loosen the filler or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.

1. After the engine is cool, loosen the pressure cap to the first stop and let the pressure out of the cooling system. Then remove the pressure cap.

2. Make sure the coolant is over the top of the radiator core.

3. Put the 9S8140 Cooling System Pressurizing Pump Group on the radiator.

4. Get the pressure reading on the gauge to 20 kPa (3 psi) more than the pressure on the pressure cap.

5. Check the radiator for outside leakage.

6. Check all connections and hoses for the cooling system for outside leakage.

7. If you do not see any outside leakage and the pressure reading on the gauge is still the same after 5 minutes, the radiator and cooling system do not have leakage. If the reading on the gauge goes down and you do not see any outside leakage, there is leakage on the inside of the cooling system. Make repairs as necessary.

Gauge for Water Temperature

Tools Needed		
8T0470	Thermistor Thermometer Group	1

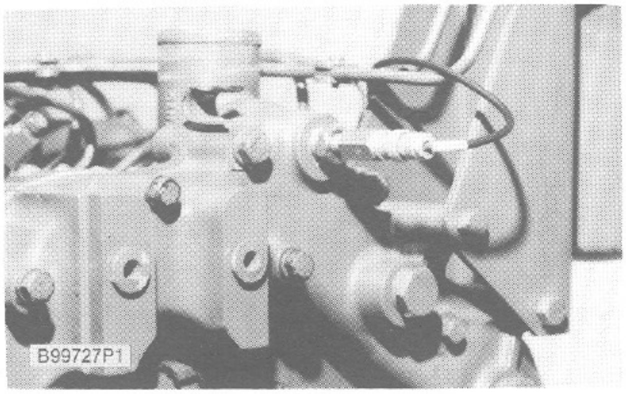
If the engine gets too hot and a loss of coolant is a problem, a pressure loss in the cooling system can be the cause. If the gauge for water temperature shows that the engine is getting too hot, look for coolant leakage.

If a place can not be found where there is coolant leakage, check the accuracy of the gauge for water temperature. Use the 8T0470 Thermistor Thermometer Group.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

Start the engine. Put a cover over part of the radiator. The reading on the gauge for water temperature must be the same as the reading on the thermistor thermometer.



8T0470 Thermistor Thermometer Group Installed
(Typical Example)

Temperature Regulator

Test procedure for water temperature regulators:

1. Remove the regulator from the engine.
2. Heat a pan of water to a temperature of 92°C (197°F).
3. Hang the regulator in the pan of hot water. Put the regulator completely under water. Do not let the regulator make contact with the pan.
4. Keep the temperature of the water at 92°C (197°F) for ten minutes. Make sure the water moves around. This keeps all of the water at the same temperature.
5. After ten minutes, remove the regulator and immediately measure the distance the regulator is opened. The distance must not be less than 37.85 mm (1.490 in).

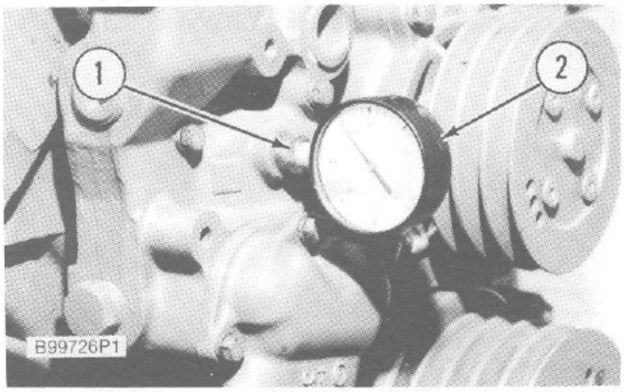
Water Pump Pressure Check

Tools Needed		
9S8138	Pressure Gauge	1
3B7722	Bushing	1

The pressure at the outlet for the water pump tells if the shunt system and water pump are operating correctly. To check the pump pressure, install pressure gauge (2) in the front cover. The pressure must be a minimum of 105 kPa (15 psi) at 2800 rpm.

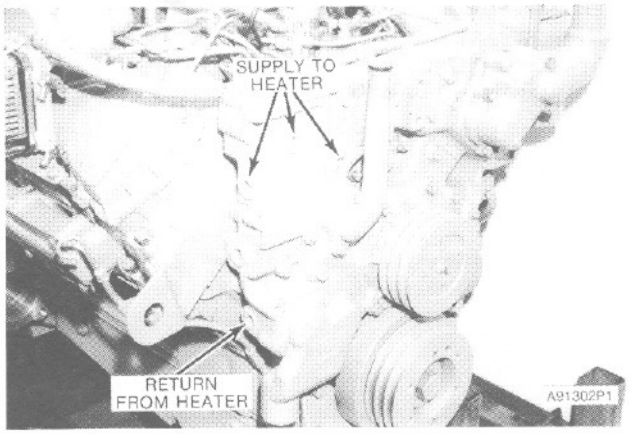
If the pump pressure is less than the minimum pressure: First, check the vent tube between the radiator top tank and the surge tank; it must have an inside diameter of approximately 4.8 mm (.19 in).

Second check to see that the shunt line has a minimum inside diameter of 19.1 mm (.75 in).



Gauge Installed
(Typical Example)
(1) 3B7722 Bushing. (2) 9S8138 Pressure Gauge.

Heater Connections

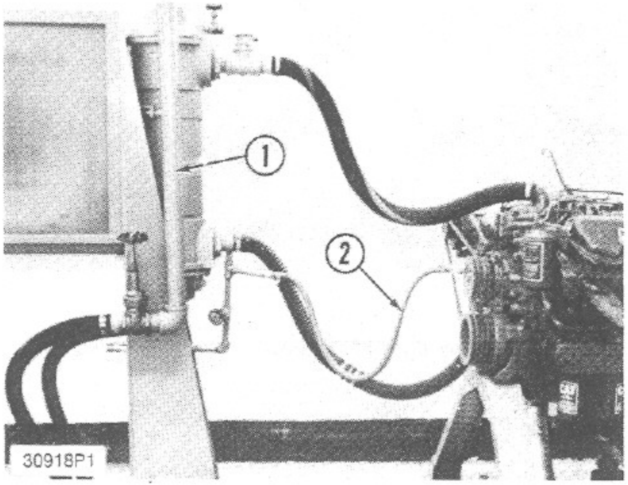


Locations Of Heater Connections

The front housing has several plugs that give access to water passages inside the housing. For the correct access points to install heater hoses, see the Locations Of Heater Connections picture.

Dynamometer Test Caution

To prevent possible damage to an engine while testing on a dynamometer, the water temperature regulators must be installed and shunt line (2) connected as shown.



Shunt Line Connected To Engine
(Typical Example)
(1) FT0790 Cooling Tower Group. (2) Shunt line.

BELT SIZE	WIDTH BELT TOP		WIDTH TOP OF PULLEY GROOVE		BELT TENSION "INITIAL"* GAUGE READING		BELT TENSION "USED"** GAUGE READING		BORROUGHS GAUGE NUMBERS	
	mm	in.	mm	in.	N	lb	N	lb	OLD GAUGE NO.	NEW GAUGE NO.
3/8	10.72	.422	9.65	.380	445 ± 22	100 ± 5	400 ± 22	90 ± 5	BT-33-95	BT-33-97
1/2	13.89	.547	12.70	.500	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-95	BT-33-97
5V	15.88	.625	15.24	.600	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-72-4-15	BT-33-72C
11/16	17.48	.688	15.88	.625	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-72-4-15	BT-33-72C
3/4	19.05	.750	17.53	.690	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-72-4-15	BT-33-72C
15/16	23.83	.983	22.30	.878	534 ± 22	120 ± 5	400 ± 44	90 ± 10	BT-33-72-4-15	BT-33-72C
8K	27.92	1.099			800 ± 22	180 ± 5	489 ± 44	110 ± 10		BT-33-109

BELT TENSION CHART

MEASURE TENSION OF BELT FARTHEST FROM THE ENGINE

*"INITIAL" BELT TENSION is for a new belt.
**"USED" BELT TENSION is for a belt which has more than 30 minutes of operation at rated speed of engine.

A10232-4P1

Basic Block

Connecting Rods And Pistons

Use the 5F9059 Piston Ring Expander to remove or install piston rings.

Use the 5P3524 Piston Ring Compressor to install pistons into ccylinder block.

Tighten the connecting rod nuts in the following step sequence:

1. Put 2P2506 Thread Lubricnt on bolt threads and seating surfaces of cap and nut.
2. Tighten both nuts to 40 ± 4 N•m (30 ± 3 lb ft).
3. Put a mark on each nut and cap.
4. Tighten each nut 60° from the mark.

The connecting rod bearings should fit tightly in the bore in the rod. If bearing joints or backs are worn (fretted), check for bore size as this is an indication of wear because of looseness.

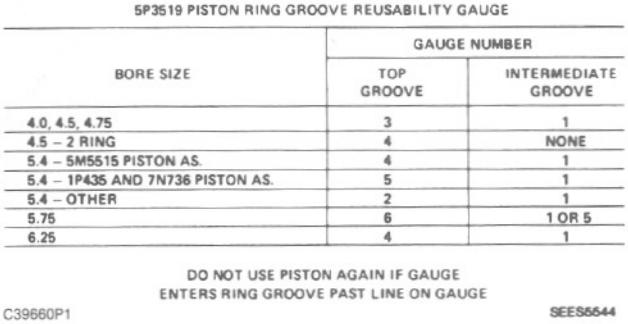
5P3519 Piston Ring Groove Gauge

A 5P3519 Piston Ring Groove Gauge is available for checking rectangular ring grooves. For instructions on the use of the gauge, see the Guideline For Reusable Parts; Pistons And Cylinder Liners, Form No. SEBF8001.

NOTE: The 5P3519 Piston Ring Groove Gauge is used to check the top ring groove only.

CATERPILLAR
SERVICE TOOL
A10746P1

Piston Ring Groove Gauge



5P3519 PISTON RING GROOVE REUSABILITY GAUGE

BORE SIZE	GAUGE NUMBER TOP GROOVE	GAUGE NUMBER INTERMEDIATE GROOVE
4.0, 4.5, 4.75	3	1
4.5 – 2 RING	4	NONE
5.4 – 5M5515 PISTON AS.	4	1
5.4 – 1P435 AND 7N736 PISTON AS.	5	1
5.4 – OTHER	2	1
5.75	6	1 OR 5
6.25	4	1

DO NOT USE PISTON AGAIN IF GAUGE
ENTERS RING GROOVE PAST LINE ON GAUGE

C39660P1 SEES5544

Piston Ring Groove Gauge Chart

Connecting Rod And Main Bearings

Bearings are available with a smaller inside diameter than the original size bearings. These bearings are for crankshafts that have been "ground" (made smaller than the original size). Main bearings are available with a larger outside diameter than the original size bearings. These bearings are for cylinder blocks that have had the bore for the main bearings "bored" (made larger than the original size).

Flywheel And Flywheel Housing

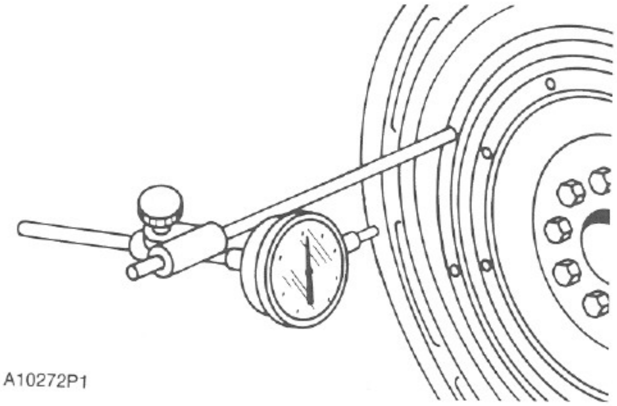
Tools Needed		
8T5096	Dial Indicator Group	1

Heat the ring gear to install it. Do not heat to more than 204°C (400°F). Install the ring gear so the chamfer on the gear teeth is next to the starter pinion when the flywheel is installed.

Face Runout (axial eccentricity) of the Flywheel Housing

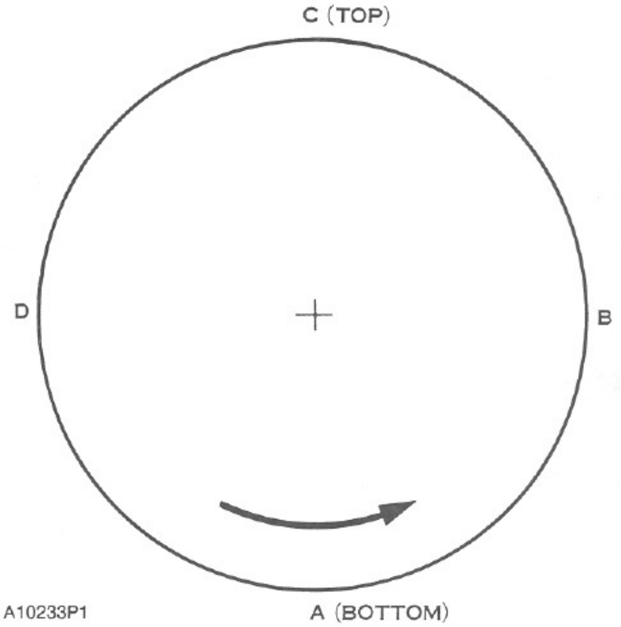
If any method other than given here is used, always remember bearing clearances must be removed to get correct measurements.

1. Fasten a dial indicator to the crankshaft flange so the anvil of the indicator will touch the face of the flywheel housing.
2. Force the crankshaft to the rear before reading the indicator at each point.



8T5096 Dial Indicator Group

3. With the dial indicator set at 0.0 mm (.00 in) at location (A), turn the crankshaft and read the indicator at locations (B), (C) and (D).
4. The difference between lower and higher measurements taken at all four points must not be more than 0.25 mm (.010 in), which is the maximum permissible face runout (axial eccentricity) of the flywheel housing.

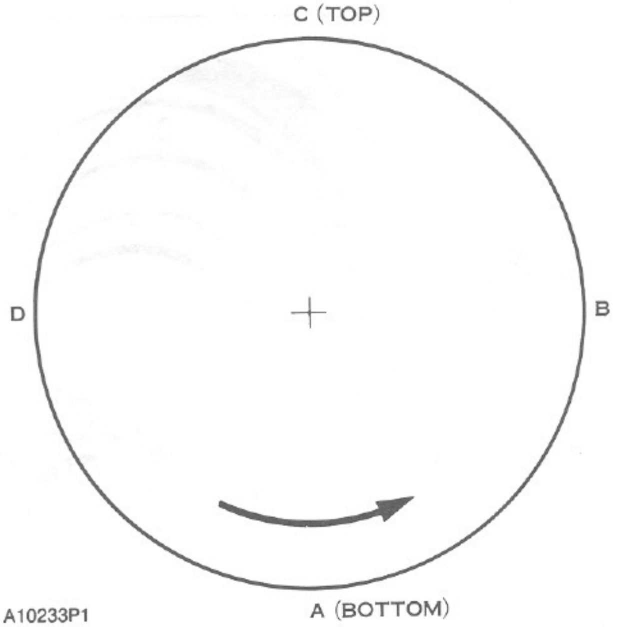


Checking Face Runout Of The Flywheel Housing
(A) Bottom. (B) Right side. (C) Top. (D) Left side.

Bore Runout (Radial Eccentricity) Of The Flywheel Housing

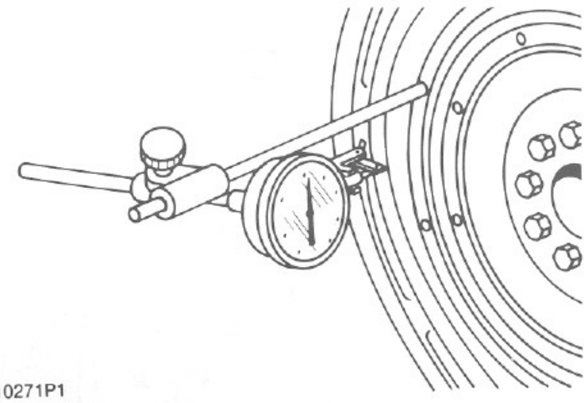
1. With the dial indicator in position at (C), adjust the dial indicator to 0.0 mm (.00 in). Push the crankshaft up against the top bearing. Write the measurement for bearing clearance on line 1 in column (C).

2. Divide the measurement from Step 1 by 2. Write this number on line 1 in columns (B) & (D).



A10233P1

Checking Bore Runout Of The Flywheel Housing



A10271P1

8T5096 Dial Indicator Group Installed

3. Turn the crankshaft to put the dial indicator at (A). Adjust the dial indicator to 0.0 mm (.00 in).

4. Turn the crankshaft counterclockwise to put the dial indicator at (B). Write down the measurement in the chart.

NOTE: Write the dial indicator measurements with their positive (+) and negative (–) notation (signs). This is necessary for making the calculations in the chart correctly.

5. Turn the crankshaft counterclockwise to put the dial indicator at (C). Write the measurement in the chart.

6. Turn the crankshaft counterclockwise to put the dial indicator at (D). Write the measurement in the chart.

7. Add lines I & II by columns.

8. Subtract the smaller number from the larger number in line III in columns (B) & (D). The result is the horizontal "eccentricity" (out of round). Line II, column (C) is the vertical eccentricity.

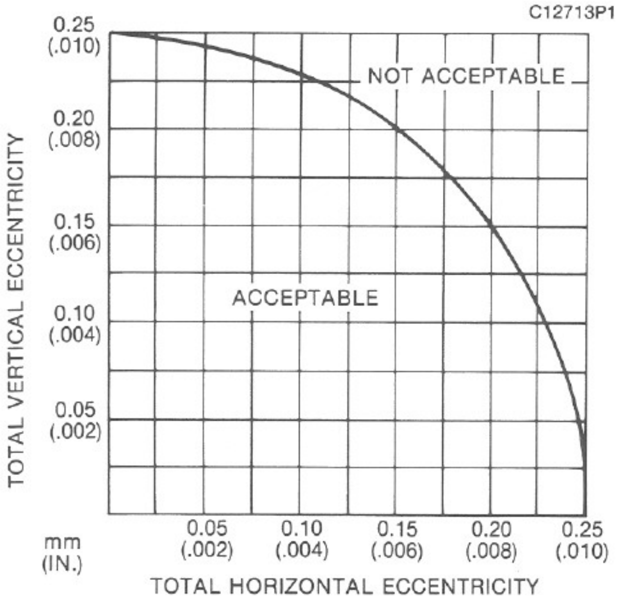
CHART FOR DIAL INDICATOR MEASUREMENTS

	Position of dial indicator				
	Line No.	A	B	C	D
Correction for bearing clearance	I	0			
Dial Indicator Reading	II	0			
Total of Line 1 & 2	III	0	**	*	**

*Total Vertical eccentricity (out of round).
**Subtract the smaller No. from the larger No. The difference is the total horizontal eccentricity.

A10234P1

9. On the graph for total eccentricity find the point of intersection of the lines for vertical eccentricity and horizontal eccentricity.

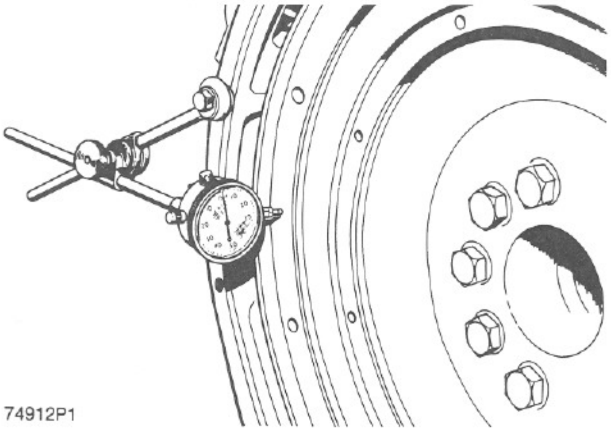


10. If the point of intersection is in the range marked "Acceptable" the bore is in alignment. If the point of intersection is in the range marked "Not Acceptable" the flywheel housing must be changed.

Face Runout (Axial Eccentricity) Of The Flywheel

1. Install the dial indicator as shown. Force the crankshaft the same way before the indicator is read so the crankshaft end clearance (movement) is always removed.

2. Set the dial indicator to read 0.0 mm (.00 in).



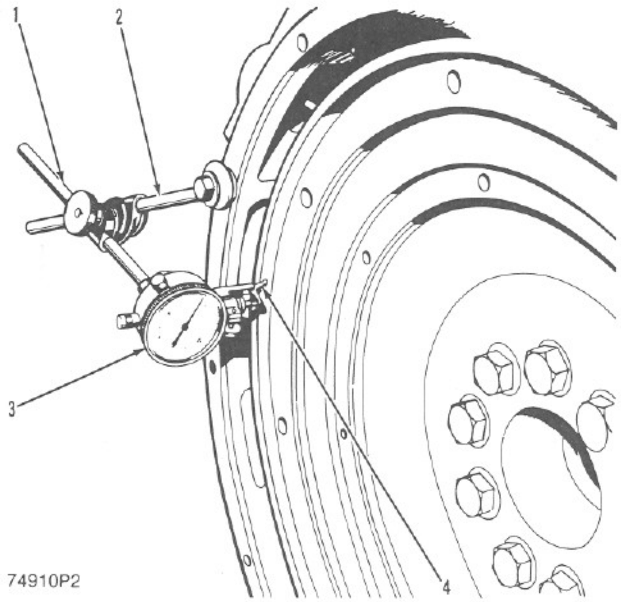
Checking Face Runout Of The Flywheel

3. Turn the flywheel and read the indicator every 90°.

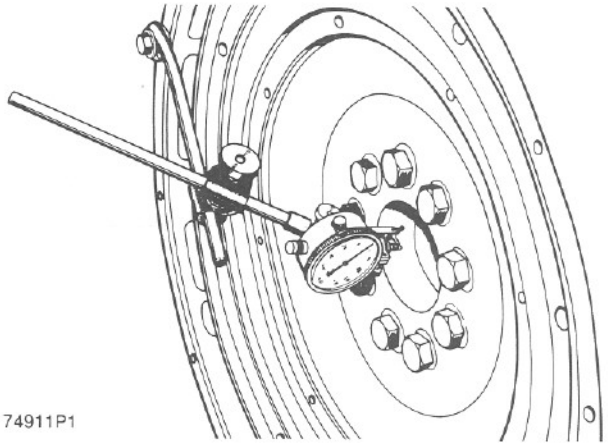
4. The difference between the lower and higher measurements taken at all four points must not be more than 0.15 mm (.006 in), which is the maximum permissible face runout (axial eccentricity) of the flywheel.

Bore Runout (Radial Eccentricity) Of The Flywheel

1. Install the dial indicator (3) and make an adjustment of the universal attachment (4) so it makes contact as shown.



Checking Bore Runout Of The Flywheel
(1) 7H1945 Holding Rod. (2) 7H1645 Holding Rod. (3) 7H1942 Indicator. (4) 7H1940 Universal Attachment.



Checking Flywheel Clutch Pilot Bearing Bore

2. Set the dial indicator to read 0.0 mm (.00 in).

3. Turn the flywheel and read the indicator every 90°.

4. The difference between the lower and higher measurements taken at all four points must not be more than 0.15 mm (.006 in), which is the maximum permissible bore runout (radial eccentricity) of the flywheel.

5. Runout (eccentricity) of the bore for the pilot bearing for the flywheel clutch, must not exceed 0.13 mm (.005 in).

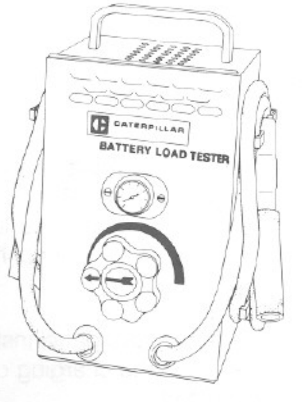
Electrical System

Test Tools For Electrical System

Tools Needed		
6V4930	Battery Load Tester	1
8T0900	AC/DC Clamp-On Ammeter	1
6V7070	Heavy-Duty Digital Multimeter or	1
6V7800	Regular-Duty Digital Multimeter	1

Most of the tests of the electrical system can be done on the engine. The wiring insulation must be in good condition, the wire and cable connections must be clean and tight, and the battery must be fully charged. If the on-engine test shows a defect in a component, remove the component for more testing.

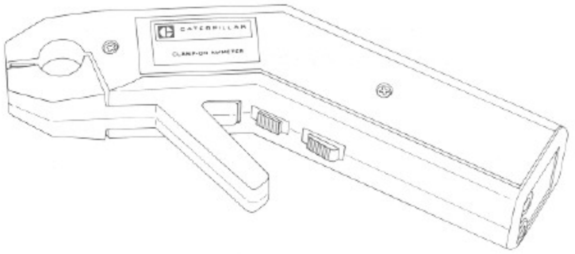
The service manual Testing And Adjusting Electrical Components, Form No. REG00636 has complete specifications and procedures for the components of the starting circuit and the charging circuit.



6V4930 Battery Load Tester

The 6V4930 Battery Load Tester is a portable unit in a metal case for use under field conditions and high temperatures. It can be used to load test all 6, 8 and 12V batteries. This tester has two heavy-duty load cables that can easily be fastened to the battery terminals, and a load adjustment knob on the front panel permits a current range up to a maximum of 700 amperes. The tester also has a thermometer to show when the safe operating temperature limit of the unit has been reached.

NOTE: Make reference to Special Instruction, Form No. SEHS8268 for complete information for use of the 6V4930 Battery Load Tester.



8T0900 AC/DC Clamp-On Ammeter

The 8T0900 AC/DC Clamp-On Ammeter is a completely portable, self-contained instrument that allows electrical current measurements to be made without breaking the circuit or disturbing the insulation on conductors. A digital display is located on the ammeter for reading current directly in a range from 1 to 1200 amperes. If an optional 6V6014 Cable is connected between this ammeter and one of the digital multimeters, current readings of less than 1 ampere can then be read directly from the display of the multimeter.

A lever is used to open the jaws over the conductor [up to a diameter of 19 mm (.75 in)], and the spring loaded jaws are then closed around the conductor for current measurement. A trigger switch that can be locked in the ON or OFF position is used to turn on the ammeter. When the turn-on trigger is released, the last current reading is held on the display for 5 seconds. This allows accurate measurements to be taken in limited access areas where the digital display is not visible to the operator. A zero control is provided for DC operation, and power for the ammeter is supplied by batteries located inside the handle.

NOTE: Make reference to Special Instruction, Form No. SEHS8420 for more complete information for use of the 8T0900 Clamp-On Ammeter.

6V7070 Heavy-Duty Digital Multimeter

The 6V7070 Heavy-Duty Digital Multimeter is a completely portable, hand held instrument with a digital display. This multimeter is built with extra protection against damage in field applications, and is equipped with seven functions and 29 ranges. The 6V7070 Multimeter has an instant ohms indicator that permits continuity checks for fast circuit inspection. It also can be used for troubleshooting small value capacitors.

The 6V7800 Regular-Duty Digital Multimeter (a low cost option to the Heavy-Duty Multimeter) is also available; however, the 6V7800 Multimeter does not have the 10A range or the instant ohms feature of the 6V7070 Multimeter.

NOTE: Make reference to Special Instruction, Form No. SEHS7734 for more complete information for use of the 6V7070 and 6V7800 Multimeters.

Battery

⚠ WARNING

Never disconnect any charging unit circuit or battery circuit cable from battery when the charging unit is operated. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Injury to personnel can be the result.

The battery circuit is an electrical load on the charging unit. The load is variable because of the condition of the charge in the battery. Damage to the charging unit will result if the connections (either positive or negative) between the battery and charging unit are broken while the charging unit is in operation. This is because the battery load is lost and there is an increase in charging voltage. High voltage will damage, not only the charging unit, but also the regulator and other electrical components.

Load test a battery that does not hold a charge when in use. To do this, put a resistance across the main connections (terminals) of the battery. For a 6, 8 or 12V battery, use a test load of three times the ampere/hour rating (the maximum test load on any battery is 500 amperes). Let the test load remove the charge (discharge) of the battery for 15 seconds and with the test load still applied, test the battery voltage. A 6V battery in good condition will show 4.5V; and 8V battery will show 6V; a 12V battery will show 9V. Each cell of a battery in good condition must show 1.6V on either a 6, 8 to 12V battery.

Charging System

The condition of charge in the battery at each regular inspection will show if the charging system operates correctly. An adjustment is necessary when the battery is constantly in a low condition of charge or a large amount of water is needed (more than one ounce of water per cell per week or per every 50 service hours).

When it is possible, make a test of the charging unit and voltage regulator on the engine, and use wiring and components that are a permanent part of the system. Off-engine (bench) testing will give a test of the charging unit and voltage regulator operation. This testing will give an indication of needed repair. After repairs are made, again make a test to give proof that the units are repaired to their original condition of operation.

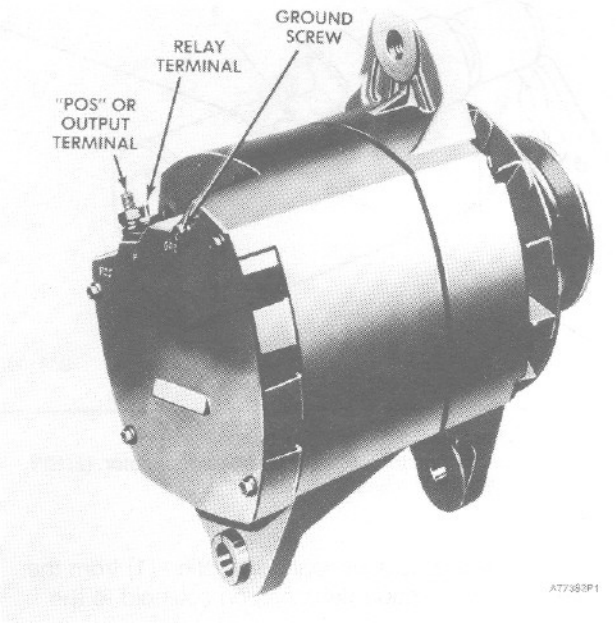
Before the start of on-engine testing, the charging system and battery must be checked as shown in the steps that follow:

1. Battery must be at least 75% (1.225 Sp Gr) fully charged and held tightly in place. The battery holder must not put too much stress on the battery.
2. Cables between the battery, starter and engine ground must be the correct size. Wires and cables must be free of corrosion and have cable support clamps to prevent stress on battery connections (terminals).
3. Leads, junctions, switches and panel instruments that have direct relation to the charging circuit must give correct circuit control.
4. Inspect the drive components for the charging unit to be sure they are free of grease and oil and have the ability to operate the charging unit.

Alternator

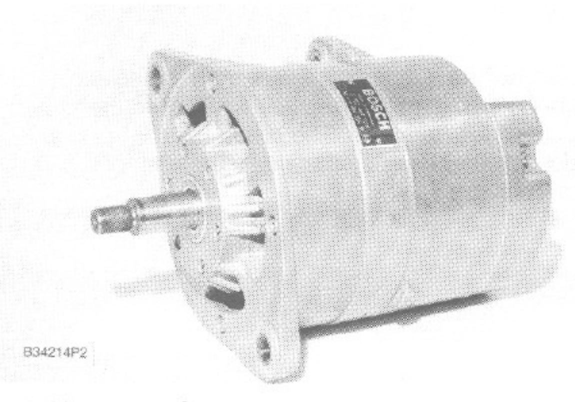
Delco-Remy

No adjustment can be made to change the rate of charge on this alternator regulator. If rate of charge is not correct, a replacement is necessary.


GROUND SCREW
RELAY TERMINAL
"POS" OR OUTPUT TERMINAL
A77352P1

3T6352 Alternator Shown

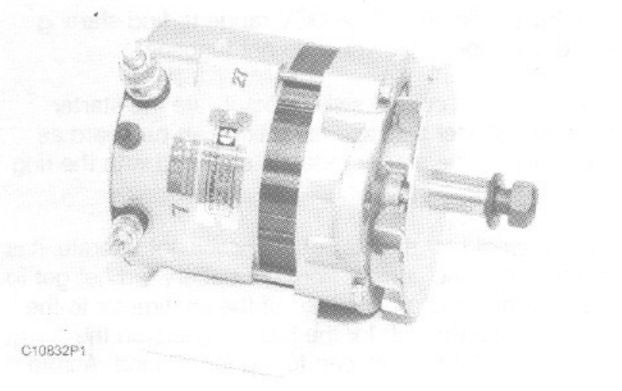
Bosch


BOSCH
B34214P2

7N9720 Alternator Shown

No adjustment can be made to change the rate of charge on this alternator regulator. If rate of charge is not correct, a replacement is necessary.

Nippondenso

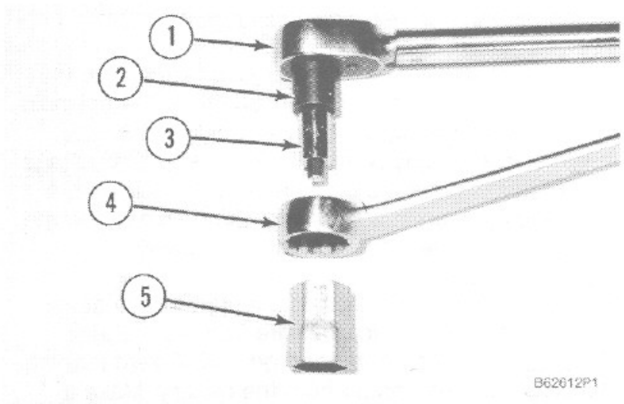


9G4574 Alternator Shown

No adjustment can be made to change the rate of charge on this alternator regulator. If rate of charge is not correct, a replacement is necessary.

Delco-Remy Alternator; Pulley Nut Tightening

Tighten nut that holds the pulley to a torque of 100 ± 7 N•m (75 ± 5 lb ft) with the tools shown.


①
②
③
④
⑤
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Tools To Tighten Alternator Pulley Nut
(1) 6V7916 Torque Wrench. (2) 8S1588 Adapter (1/2" female to 3/8" male). (3) FT1697 Socket. (4) 8H8517 Combination Wrench (1 1/8"). (5) FT1696 Wrench.

Starting System

Use the multimeter in the DCV range to find starting system components which do not function.

Move the start control switch to activate the starter solenoid. Starter solenoid operation can be heard as the pinion of the starter motor is engaged with the ring gear on the engine flywheel.

If the solenoid for the starter motor will not operate, it is possible that the current from the battery did not get to the solenoid. Fasten one lead of the multimeter to the connection (terminal) for the battery cable on the solenoid. Put the other lead to a good ground. A zero reading is an indication that there is a broken circuit from the battery. More testing is necessary when there is a voltage reading on the multimeter.

The solenoid operation also closes the electric circuit to the motor. Connect one lead of the multimeter to the solenoid connection (terminal) that is fastened to the motor. Put the other lead to a good ground. Activate the starter solenoid and look at the multimeter. A reading of battery voltage shows the problem is in the motor. The motor must be removed for further testing. A zero reading on the multimeter shows that the solenoid contacts do not close. This is an indication of the need for repair to the solenoid or an adjustment to be made to the starter pinion clearance.

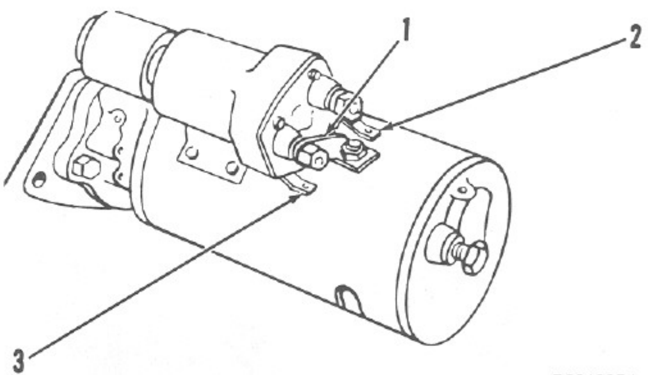
Make a test with one multimeter lead fastened to the connection (terminal) for the small wire at the solenoid and the other lead to the ground. Look at the multimeter and activate the starter solenoid. A voltage reading shows that the problem is in the solenoid. A zero reading is an indication that the problem is in the start switch or the wires for the start switch.

Fasten one multimeter lead to the start switch at the connection (terminal) for the wire from the battery. Fasten the one lead to a good ground. A zero reading indicates a broken circuit from the battery. Make a check of the circuit breaker and wiring. If there is a voltage reading, the problem is in the start switch or in the wires for the start switch.

A starter motor that operates too slow can have an overload because of too much friction in the engine being started. Slow operation of the starter motor can also be caused by a short circuit, loose connections and/or dirt in the motor.

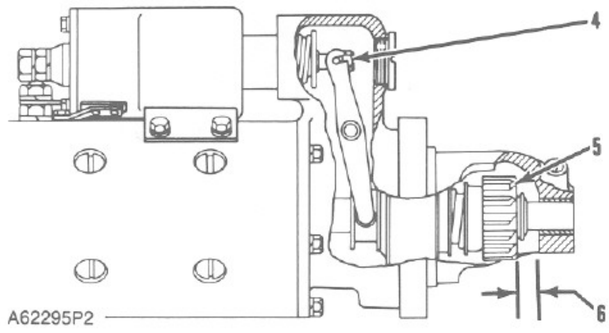
Pinion Clearance Adjustment (Delco-Remy)

When the solenoid is installed, make an adjustment of the pinion clearance. The adjustment can be made with the starter motor removed.



Connection For Checking Pinion Clearance
(1) Connector from motor terminal on solenoid to motor. (2) SW terminal. (3) Ground terminal.

1. Install the solenoid without connection (1) from the MOTOR connection (terminal) on solenoid to the motor.
2. Connect a battery, of the same voltage as the solenoid, to the terminal (2), marked SW.
3. Connect the other side of battery to ground terminal (3).
4. Connect for a moment, a wire from the solenoid connection (terminal) marked MOTOR to the ground connection (terminal). The pinion will shift to crank position and will stay there until the battery is disconnected.



Pinion Clearance Adjustment
(4) Shaft nut. (5) Pinion. (6) Pinion clearance.

5. Push the pinion toward the commutator end to remove free movement.

6. Pinion clearance (6) must be 8.3 to 9.9 mm (.33 to .39 in).

7. To adjust pinion clearance, remove plug and turn nut (4).

Pinion Clearance Adjustment (Prestolite)

There are two adjustments on this type motor. They are end play for the armature and pinion clearance.

End Play For The Armature

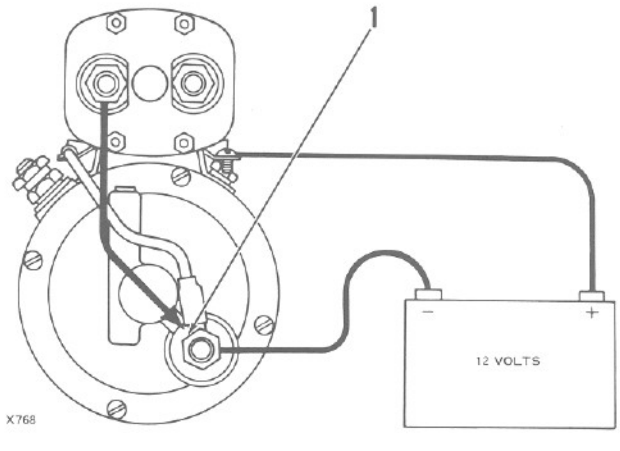
The correct end play for the armature is 0.13 to 0.76 mm (.005 to .030 in). The adjustment is made by adding or removing thrust washers on the commutator end of the armature shaft.

Pinion Clearance Adjustment

1. To adjust the pinion distance, connect the 24V solenoid to a 12 volt battery (12V solenoid to a 6V battery) as shown. For a short moment, connect a wire from the "motor" stud of the solenoid to the stud at (1) in the commutator end. This moves the solenoid and drive into the cranking position.

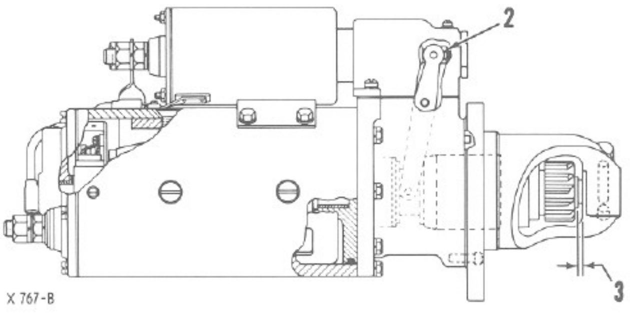
Disconnect the wire.

NOTE: The drive is in the cranking position until the battery is disconnected.



Connections For Adjustment Of The Pinion Clearance
(1) Stud

2. Push the drive toward the commutator end of the motor to eliminate any slack movement in the linkage and measure the distance between the thrust washer. The distance (3) must be 0.51 to 1.27 mm (.020 to .050 in).



Pinion Clearance Adjustment
(2) Adjusting nut. (3) Distance.

3. Remove the plug. Turn the adjusting nut (2) in or out as necessary to get this distance.

4. Install the plug.

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Troubleshooting

Introduction to the Troubleshooting Guide

This troubleshooting guide, when followed exactly as shown, can be an aid for the serviceman to find the cause of existing problems. The information from the measurements will also show proof if there is any basis for the complaint.

Be sure to get a good description of the problem from the operator and/or the person who owns the vehicle. What they tell you about the problem can save you time and make the repair job faster and easier.

Low Power and High Fuel Consumption Problems

The troubleshooting charts that follow provide a definite sequence to be followed for a logical, one by one elimination of many variables. The encircled numbers do not designate steps, but are references to detailed instructions that can not be shown on the chart. Always read the written material that corresponds with the encircled numbers on the charts.

The Primary Engine Tests consist of quick and easy procedures that could identify the problem with a minimum loss of time. Always make these tests before starting the more involved troubleshooting charts.

The necessary instruments to check each problem in sequence are shown on the chart. If the correct instrument is not available for the test, do not continue. The vehicle must be sent to a shop where the necessary tools are available.

Whenever a problem is found and corrected, always run the test again to that point to be sure there is not a combination of problems. When the problem has been corrected and the complaint resolved, stop the test. Do not continue through the complete procedure just because it is there.

When investigating possible causes, follow the letter sequence shown. Possible causes are arranged in order from more probable/easiest to check to less probable/more complex to check.

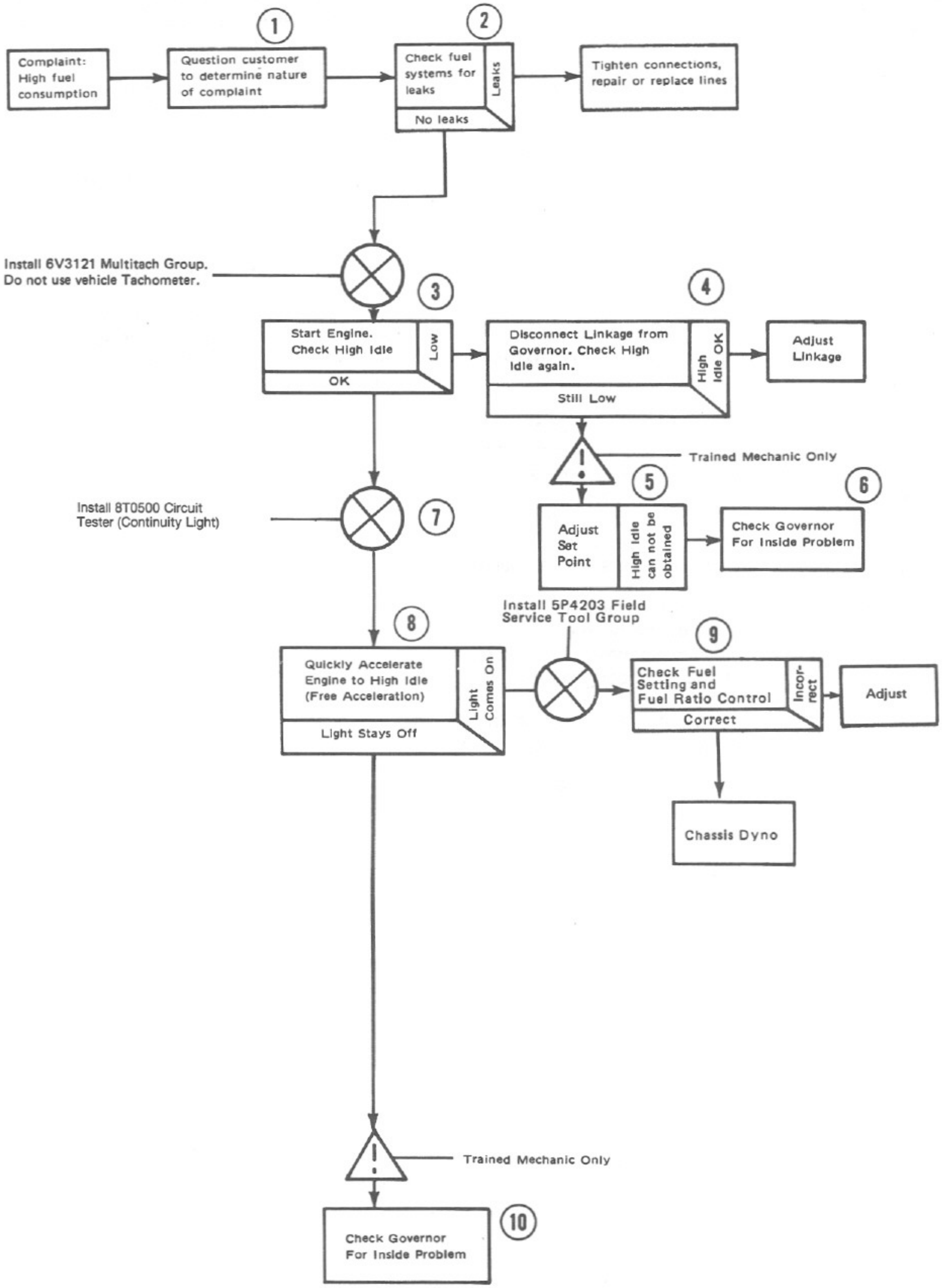
Other Problems: Vehicle Or Vehicle Operation, Misfiring And Running Rough, Too Much Exhaust Smoke, Difficult Starting, Cooling System, Loss Of Coolant, Or Fuel In Crankcase Oil.

The probable causes of a problem are given in the order they most commonly take place. Check the probable causes in the same order that they are given. When troubleshooting, use the section on recommended procedures which follow each chart to check and make the necessary corrections for each probable cause.

Engine Vibration Problem

The troubleshooting chart provides a definite sequence to be followed for a logical procedure to determine the frequency and amplitude of vibration so that the source of the vibration can be located and corrected.

PRIMARY ENGINE TEST
FOR HIGH FUEL CONSUMPTION


Complaint: High fuel consumption
① Question customer to determine nature of complaint
② Check fuel systems for leaks
Leaks
Tighten connections, repair or replace lines
No leaks
Install 6V3121 Multitach Group. Do not use vehicle Tachometer.
③ Start Engine. Check High Idle
Low
OK
④ Disconnect Linkage from Governor. Check High Idle again.
High Idle OK
Adjust Linkage
Still Low
Trained Mechanic Only
⑤ Adjust Set Point
High Idle can not be obtained
⑥ Check Governor For Inside Problem
Install 8T0500 Circuit Tester (Continuity Light)
⑦
⑧ Quickly Accelerate Engine to High Idle (Free Acceleration)
Light Comes On
Light Stays Off
Install 5P4203 Field Service Tool Group
⑨ Check Fuel Setting and Fuel Ratio Control
Incor-rect
Adjust
Correct
Chassis Dyno
Trained Mechanic Only
⑩ Check Governor For Inside Problem

Primary Engine Test for Low Power

1. The customer must be asked many questions to determine whether his complaint is valid, or whether his diagnosis of an actual problem is correct.

Some of the questions that must be asked are as follows:

a. Does poor performance occur when the vehicle is operated at steady speed on a level road surface, or when vehicle is pulled up a grade?

A positive response to either or both of the above conditions would indicate a low power (steady state) problem. Begin with Low Power Diagnosis.

b. Does the poor performance always occur under the same conditions or is the problem intermittent (happens only occasionally)?

This is a very important line of questioning to pursue. Any constant performance problem can normally be identified and the problem corrected. If an intermittent problem exists, the mechanic must be aware that the condition is only occasional, and must run certain tests several times in an attempt to force the malfunction condition. If the condition is not duplicated, the diagnosis that no problem exists will be incorrect, and the vehicle operator will again be confronted with the problem somewhere out on the road.

c. Was the engine running rough or misfiring when the poor performance was noticed?

A positive response to this questions will indicate the need to isolate the bad cylinder(s) and correct the problem. See section Cylinder Misfire.

2. Check the crankcase oil level and the coolant level of the radiator. Start the engine and get to normal operating temperature. A slightly lower rpm (15 rpm below low limit) should be expected for the engine in vehicle than the rpm shown in the Fuel Setting And Related Information Fiche. This is caused by the parasitic loads of the engine accessories involved.

3. With the engine running, the throttle must have enough travel for the governor control lever to break over (go past the normal governor stop for high idle position) a small amount when the throttle pedal is fully depressed. If full travel is not available, disconnect throttle linkage from governor lever. With throttle linkage disconnected, full travel of governor lever will indicate linkage problems, and the linkage will have to be adjusted. Limited travel of the governor lever will indicate a problem within the governor.

4. Only a mechanic with the correct training should change the set point (balance point). The procedure is given in the Service Manual under the subject Governor Adjustments.

5. If the set point (balance point) cannot be made correct with the high idle adjustment screw, there is a problem inside the governor. Disassemble the governor and check for damaged parts or wrong parts installed in the governor. Some common problems are worn bushings, worn spring seat, or a broken or wrong governor spring.

6. Before 8T0500 Circuit Tester is installed, be sure to test the light for correct operation. Test light must come on when the clip of the wire is placed against the probe of the light (replace batteries or bulb if light does not come on).

NOTE: If light comes on and stays on when attached to governor, then insulation is bad or installed wrong in torque spring group or brass terminal. This must be corrected before test is performed.

7. With the continuity light installed, quickly push accelerator pedal all the way to the floor. If the fuel control shaft and governor functions properly, the continuity light will come on during this free acceleration until high idle is maintained.

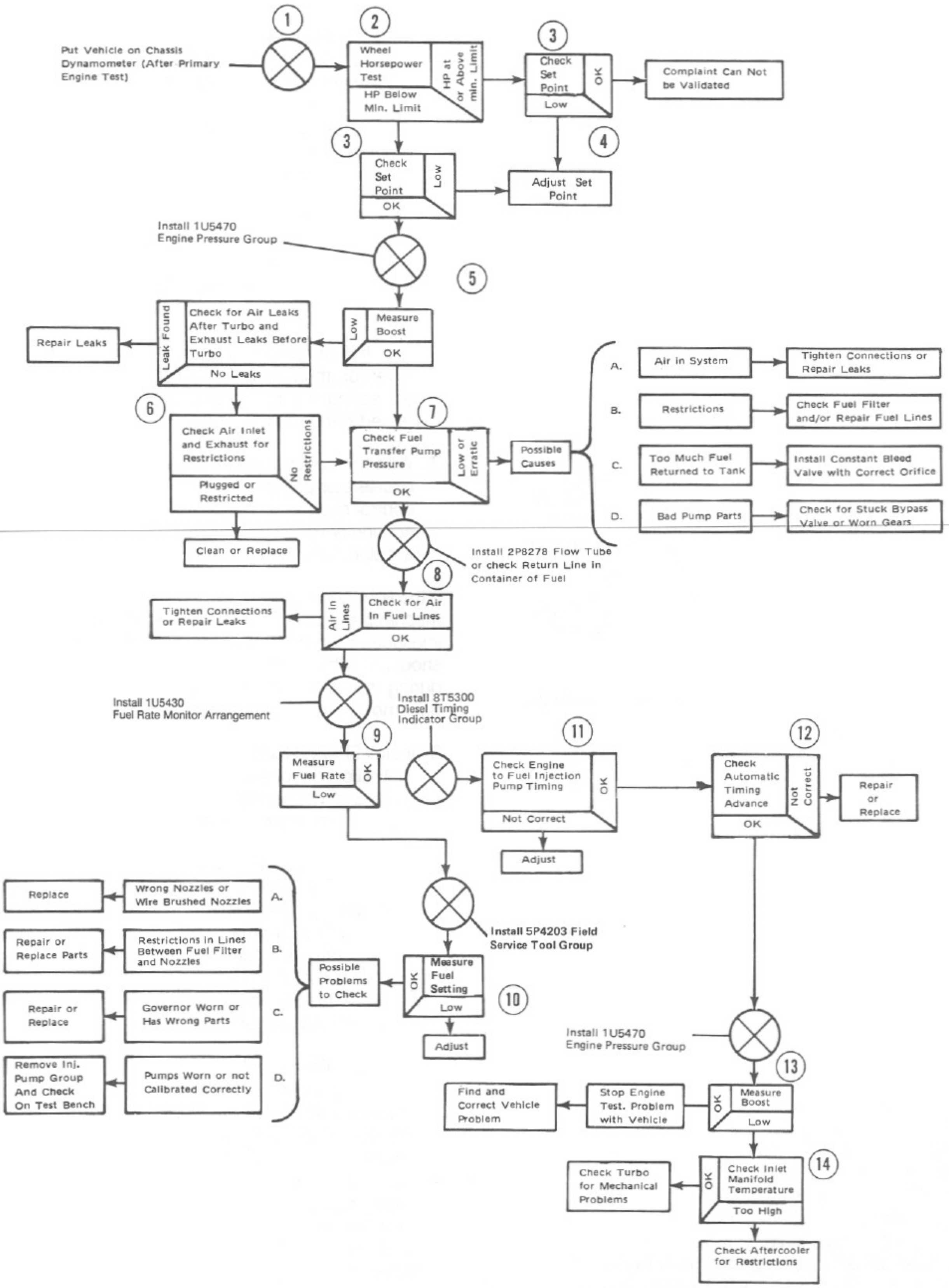
If the light comes on, this is an indication that the mechanical movement of the governor and fuel injection pump parts operate properly. The fuel setting should now be checked. If the light does not come on during free acceleration, check for a problem inside the governor.

8. Install 5P4203 Field Service Tool Group. Check the fuel ratio control and the fuel setting dimensions. Compare the results with the dimensions given in the Fuel Setting and Related Information Fiche.

If the fuel ratio control or the fuel settings are not correct, they must be adjusted to the settings given in the Fuel Setting and Related Information Fiche. Only a mechanic with the correct training should adjust the fuel ratio control and fuel settings. The procedure to check and adjust the fuel ratio control and the fuel setting is in this Service Manual under the subject Fuel Ratio Control Adjustment and Fuel Setting.

9. If the test light still does not come on, this means that the fuel control shaft is not moving due to a problem inside the governor or a problem inside fuel injection pump housing. The governor should be checked for worn parts. The fuel injection pump housing should be checked for a worn fuel control shaft or its bore, or a fuel injection pump installed with sleeve not engaged with the lever on the fuel control shaft. The problem must be found and corrected.

LOW POWER TROUBLESHOOTING
(Diagnosis with Chassis Dynamometer)


1
Put Vehicle on Chassis Dynamometer (After Primary Engine Test)
2
Wheel Horsepower Test
HP at or Above min. Limit
HP Below Min. Limit
3
Check Set Point
OK
Low
Complaint Can Not be Validated
3
Check Set Point
Low
OK
4
Adjust Set Point
Install 1U5470 Engine Pressure Group
5
Measure Boost
Low
OK
Check for Air Leaks After Turbo and Exhaust Leaks Before Turbo
Leak Found
No Leaks
Repair Leaks
6
Check Air Inlet and Exhaust for Restrictions
No Restrictions
Plugged or Restricted
Clean or Replace
7
Check Fuel Transfer Pump Pressure
Low or Erratic
OK
Possible Causes
A. Air in System
Tighten Connections or Repair Leaks
B. Restrictions
Check Fuel Filter and/or Repair Fuel Lines
C. Too Much Fuel Returned to Tank
Install Constant Bleed Valve with Correct Orifice
D. Bad Pump Parts
Check for Stuck Bypass Valve or Worn Gears
Install 2P8278 Flow Tube or check Return Line in Container of Fuel
8
Check for Air In Fuel Lines
Air in Lines
OK
Tighten Connections or Repair Leaks
Install 1U5430 Fuel Rate Monitor Arrangement
9
Measure Fuel Rate
OK
Low
Install 8T5300 Diesel Timing Indicator Group
11
Check Engine to Fuel Injection Pump Timing
OK
Not Correct
Adjust
12
Check Automatic Timing Advance
Not Correct
OK
Repair or Replace
Install 5P4203 Field Service Tool Group
10
Measure Fuel Setting
OK
Low
Adjust
Possible Problems to Check
A. Wrong Nozzles or Wire Brushed Nozzles
Replace
B. Restrictions in Lines Between Fuel Filter and Nozzles
Repair or Replace Parts
C. Governor Worn or Has Wrong Parts
Repair or Replace
D. Pumps Worn or not Calibrated Correctly
Remove Inj. Pump Group And Check On Test Bench
Install 1U5470 Engine Pressure Group
13
Measure Boost
OK
Low
Stop Engine Test. Problem with Vehicle
Find and Correct Vehicle Problem
14
Check Inlet Manifold Temperature
OK
Too High
Check Turbo for Mechanical Problems
Check Aftercooler for Restrictions

Low Power Troubleshooting

(Diagnosing with Chassis Dynamometer)

1. Preparation of vehicle for wheel horsepower test (consult dynamometer manufacturer's operating instructions for specific details on correct operation).

NOTE: Always perform the Primary Engine Test procedure before vehicle is installed on chassis dynamometer.

Calculate the allowable limits that the customer can expect from his engine and present these figures to him.

Caterpillar engines are rated with the conditions that follow:

Barometric pressure = 747 mm (29.4 in) of mercury
Inlet air temperature = 29°C (85°F) at air cleaner inlet
Fuel gravity = API gravity of 35 at 16°C (60°F)

Measure and record these variables.

a. Place vehicle on the chassis dynamometer. Tie the vehicle in a way that will not add any load to the drive wheels. Do not pull wheels down into dynamometer drive rolls.

Check the radiator coolant level, crankcase oil level, tire pressure, tire condition, remove rocks from the tire tread and connect exhaust system.

NOTICE

Recapped tires should be run on a chassis dynamometer only at the customer's own risk.

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b. Operate vehicle at 60% of rated speed with moderate load until oil and coolant temperatures reach their normal range for operation.

NOTICE

If there is a heavy vibration, drive shaft whip, tire bounce, etc., do not continue with dynamometer test until cause of the problem is corrected. Engines that have had new internal parts installed should be operated on a run-in schedule before operation at full load. For run-in schedule information, make reference to General Instructions section of this Service Manual.

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2. Put transmission in direct gear and the differential in the highest speed ratio. Operate vehicle at maximum engine speed and increase chassis dynamometer load until a speed of 50 rpm less than rated speed is reached (continuity light should be on). Maintain this speed for one minute and record the engine speed and wheel horsepower.

NOTE: If horsepower is low and poor maintenance is suspected, remove air cleaner and check horsepower again to see if a plugged air cleaner could be the problem.

3a. If the wheel horsepower is correct, find the set point (balance point) of the engine (speed at which the load stop pin just touches the torque spring or stop bar). At this point the continuity light should flicker (go off and on dimly).

If the set point (balance point) is correct, then the low power complaint cannot be validated. No further test or repairs are necessary.

If the set point (balance point) is low, see Procedure No. 4.

3b. If the wheel horsepower is below the correct value, find the set point (balance point) of the engine (speed at which the load stop pin just touches the torque spring or stop bar). At this point the continuity light should flicker (go off and on dimly).

If the set point (balance point) is correct, see Procedure No. 5.

If the set point (balance point) is low, see Procedure No. 4.

4. If the set point (balance point) is low, the high idle will have to be increased to raise the set point (balance point) to the correct rpm (the point at which the continuity light just comes on).

NOTE: If the set point (balance point) is still low and high idle has been adjusted to maximum, disengage clutch while maximum throttle position is maintained. Now observe high idle rpm and, if lower than previously adjusted, check frame-to-engine-mount. A damaged or loose engine mount may put the linkage in a bind and prevent maximum governor position at load conditions.

5. If the set point (balance point) was correct and the wheel horsepower was low, install the 1U5470 Engine Pressure Group and do the wheel horsepower test again as shown in Procedure No 2.

At full load rpm, measure the boost and the fuel pressure. See Fuel Setting and Related Information Fiche to find the correct boost pressure for a particular engine (since the engine is in vehicle, be sure to make reference to the General Notes in the Fuel Setting and Related Information Fiche to determine the correct boost pressure with air cleaner and muffler installed). If boost is low, check connections ahead of turbine side of turbocharger for exhaust leaks and connections after compressor side of turbocharger for inlet air leaks.

6. Check the air inlet restriction and exhaust back pressure.

Air flow through the air cleaner and piping must not have a vacuum restriction (negative pressure difference between atmospheric air and air that has gone through air cleaner) of more than 635 mm (25 in) of water. Back pressure from the exhaust (pressure difference measurement between exhaust outlet elbow and atmospheric air) must not be more than 1016 mm (40 in) of water.

Make a visual inspection of the air inlet system and check for damage to piping, rags or obstructions in the inlet piping, or damage to the rain cap or the cap pushed too far on the inlet pipe. If no damage is found, check inlet restriction with a new air cleaner element.

If there is too much exhaust restriction, make a visual inspection of the exhaust piping and muffler. If no visual damage can be found, the exhaust piping may have to be removed and the exhaust restriction measured again to see if problem is corrected.

7. The fuel transfer pump pressure (measured at plug on top of fuel pump housing) must not be less than 140 kPa (20 psi) at full load conditions. Normal fuel pressure at full load rpm is 205 ± 35 kPa (30 ± 5 psi). If fuel pressure is low or erratic, check for the conditions that follow in the order shown:

A. Air in the Fuel System . . . Disconnect the fuel return line at the tank. Place this end of the line in a container of fuel to see if air bubbles are present with the engine running. If air bubbles are observed, check for loose connections or other line leaks ahead of fuel transfer pump.

B. Restrictions . . . Check for a plugged fuel filter or crimped (damaged) fuel lines.

C. Too Much Fuel Returned to Tank . . . Block the fuel return line to stop all fuel returned to tank. Check fuel pressure again, and, if a significant pressure increase is observed, an incorrect constant bleed orifice may be the problem. Install the correct orifice.

NOTICE

Do not run the engine under load for more than 5 minutes with return line blocked.

D. Damaged Fuel Transfer Pump Parts . . . Check bypass valve to see if dirt or other debris could make the valve stick. Clean or replace valve if damaged. If bypass valve is good, remove and disassemble fuel transfer pump to check for wear in the gears.

8. A very small amount of air in the fuel may not affect the transfer pump fuel pressure, but could affect the performance at the nozzles. The 2P8278 Flow Tube can be installed ahead of the fuel transfer pump. This will allow a visual check of any air in the fuel when the engine is running. Another method to check for air in the fuel is to put the fuel tank end of the fuel return line in a container of fuel.

9. Install the 6V7925 Fuel Rate Indicator according to Special Instruction, Form No. SEHS8346. The specified fuel rate at full load is given in the Fuel Setting And Related Information Fiche.

Do the wheel horsepower test again as shown in Procedure No. 2, but this time record the fuel rate and rpm.

NOTE: This fuel system has a constant flow of fuel that is returned to the fuel tank. This orifice must be blocked before accurate fuel rate readings can be taken. Do not run the engine under load for more than 5 minutes with return line blocked.

10. If the fuel rate was too low, install 5P4203 Field Service Tool Group and check the fuel system setting. The correct fuel system setting is given in Fuel Setting And Related Information Fiche. If fuel system setting is not correct, the adjustment procedure is shown in the Testing and Adjusting section of this Service Manual under the subject Fuel System Setting.

If the fuel rate was low, and the fuel system setting is correct, check the items that follow in the sequence shown:

A. Remove nozzles and check to see if they are the correct nozzles for your engine or if they have been wire brushed. Either condition will affect performance.

B. Check for any restrictions to fuel flow in lines between fuel filter and nozzles. Any sharp bend in the lines could cause a restriction of fuel delivery.

C. Check governor for worn parts. A worn bushing or worn spring seat can change governor operation. Also check to see if the correct governor spring is installed.

D. Check fuel injection pumps for wear and for the correct calibration. Put the fuel injection pump group on the fuel injection test bench. Perform a fuel delivery test to determine if the correct amount of fuel is delivered by each pump.

11. Use the 8T5300 Diesel Timing Indicator Group to check the timing of the fuel injection pump camshaft to the engine camshaft. See Fuel System of the Testing and Adjusting section of this Service Manual for the subject Checking Engine Timing And Automatic Timing Advance Unit With 8T5300 Timing Indicator Group.

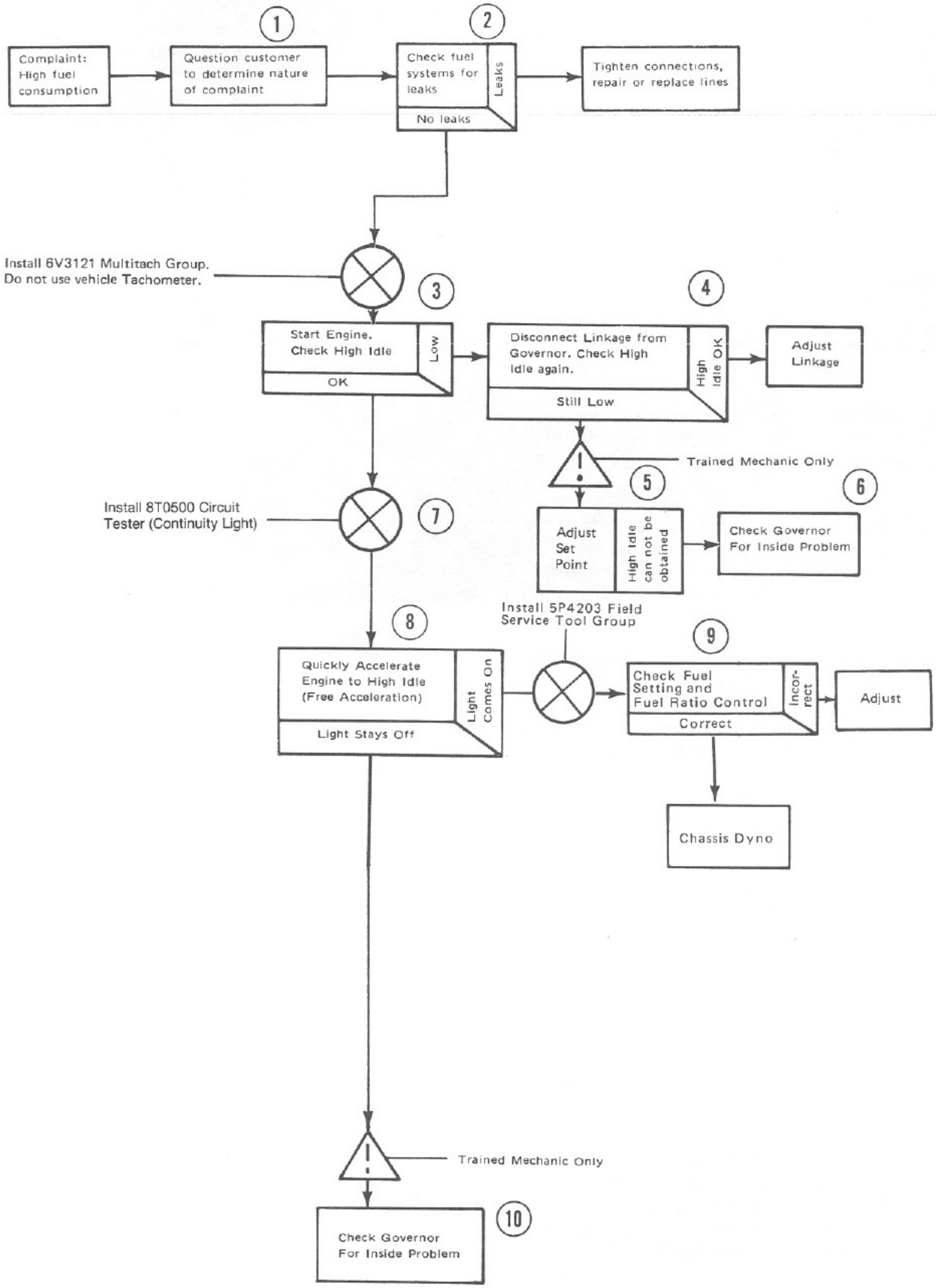
12. Use the 8T5300 Timing Indicator Group to check the automatic timing advance unit. Check to see that the advance is smooth and that the amount of advance is correct. See Fuel System of the Testing and Adjusting section of this Service Manual for the subject Checking Engine Timing And Automatic Timing Advance Unit With 8T5300 Timing Indicator Group.

If rpm, timing, and fuel rate are found to be within specifications, the engine should produce acceptable power (unless engine has excessive internal friction, ie, high crankcase oil level). When all the above conditions are within specifications, and the wheel horsepower is still lower than expected, some component of the vehicle must be absorbing too much power. Do not continue with engine troubleshooting, but locate and correct the problem with the vehicle. (Caterpillar is not responsible for problems with vehicle).

13. Measure the boost again as detailed in Procedure No. 5. If rpm, timing, fuel rate and boost are found to be within specifications, the engine should produce acceptable power (unless engine has excessive internal friction, i.e., high crankcase oil level). When all the above conditions are within specifications, and the wheel horsepower is still lower than expected, some component of the vehicle must be absorbing too much power. Do not continue with engine troubleshooting, but locate and correct the problem with the vehicle. (Caterpillar is not responsible for problems with vehicle).

14. If boost is still low, check inlet manifold temperature. If temperature is too high, check the aftercooler for possible restrictions to the coolant. This condition reduces the amount of air in cylinder for combustion (since warmer air is less dense). If manifold temperature is correct, check the turbocharger for mechanical problems (ie, wrong nozzles, worn bearings).

PRIMARY ENGINE TEST
FOR HIGH FUEL CONSUMPTION


1
2
Complaint: High fuel consumption
Question customer to determine nature of complaint
Check fuel systems for leaks
Leaks
No leaks
Tighten connections, repair or replace lines
Install 6V3121 Multitach Group. Do not use vehicle Tachometer.
3
4
Start Engine. Check High Idle
Low
OK
Disconnect Linkage from Governor. Check High Idle again.
High Idle OK
Still Low
Adjust Linkage
Trained Mechanic Only
5
6
Install 8T0500 Circuit Tester (Continuity Light)
7
Adjust Set Point
High Idle can not be obtained
Check Governor For Inside Problem
8
Install 5P4203 Field Service Tool Group
9
Quickly Accelerate Engine to High Idle (Free Acceleration)
Light Comes On
Light Stays Off
Check Fuel Setting and Fuel Ratio Control
Incor-rect
Correct
Adjust
Chassis Dyno
Trained Mechanic Only
Check Governor For Inside Problem
10

Primary Engine Test for High Fuel Consumption

1. Fuel consumption records must be available before the high fuel consumption complaint can be verified. If symptoms indicate low power, then the low power test should be conducted first, because it could be the cause of the fuel consumption problem. This Primary Engine Test for High Fuel Consumption is the same as the Primary Engine Test for Low Power.

2. Visually inspect the fuel system from the fuel tank to the fuel injection lines to see if there are any indications of fuel leaks. Tighten any loose connections found and, if necessary, replace lines that can not be repaired.

3. Check the crankcase oil level and the coolant level of the radiator. Start the engine and get to normal operating temperature. A slightly lower rpm (15 rpm below low limit) should be expected for the engine in vehicle than the rpm shown in the Fuel Setting And Related Information Fiche. This is caused by the parasitic loads of the engine accessories involved.

4. With the engine running, the throttle must have enough travel for the governor control lever to break over (go past the normal governor stop for high idle position) a small amount when the throttle pedal is fully depressed. If full travel is not available, disconnect throttle linkage from governor lever. With throttle linkage disconnected, full travel of governor lever will indicate linkage problems, and the linkage will have to be adjusted. Limited travel of the governor lever will indicate a problem within the governor.

5. Only a mechanic with the correct training should change the set point (balance point) adjustment. The procedure is given in this Service Manual under the subject Governor Adjustments.

6. If high idle rpm can not be made correct with the high idle adjustment screw, there is a problem inside the governor. Disassemble the governor and check for damaged parts or wrong parts installed in the governor. Some common problems are worn bushings, worn spring seat, or a broken or wrong governor spring.

7. Before 8T0500 Circuit Tester is installed, be sure to test the light for correct operation. Test light must come on when the clip of the wire is placed against the probe of the light (replace batteries or bulb if light does not come on).

NOTE: If light comes on and stays on when attached to governor, the insulation is bad or installed wrong in torque spring group or brass terminal. This must be corrected before test is performed.

8. With the continuity light installed, quickly push accelerator pedal all the way to the floor. If the fuel control shaft and governor function properly, the continuity light will come on during this free acceleration until high idle is maintained.

If the light comes on, this is an indication that the mechanical movement of the governor and fuel injection pump parts operate properly. The fuel setting should now be checked. If the light does not come on during free acceleration, check for a problem inside the governor.

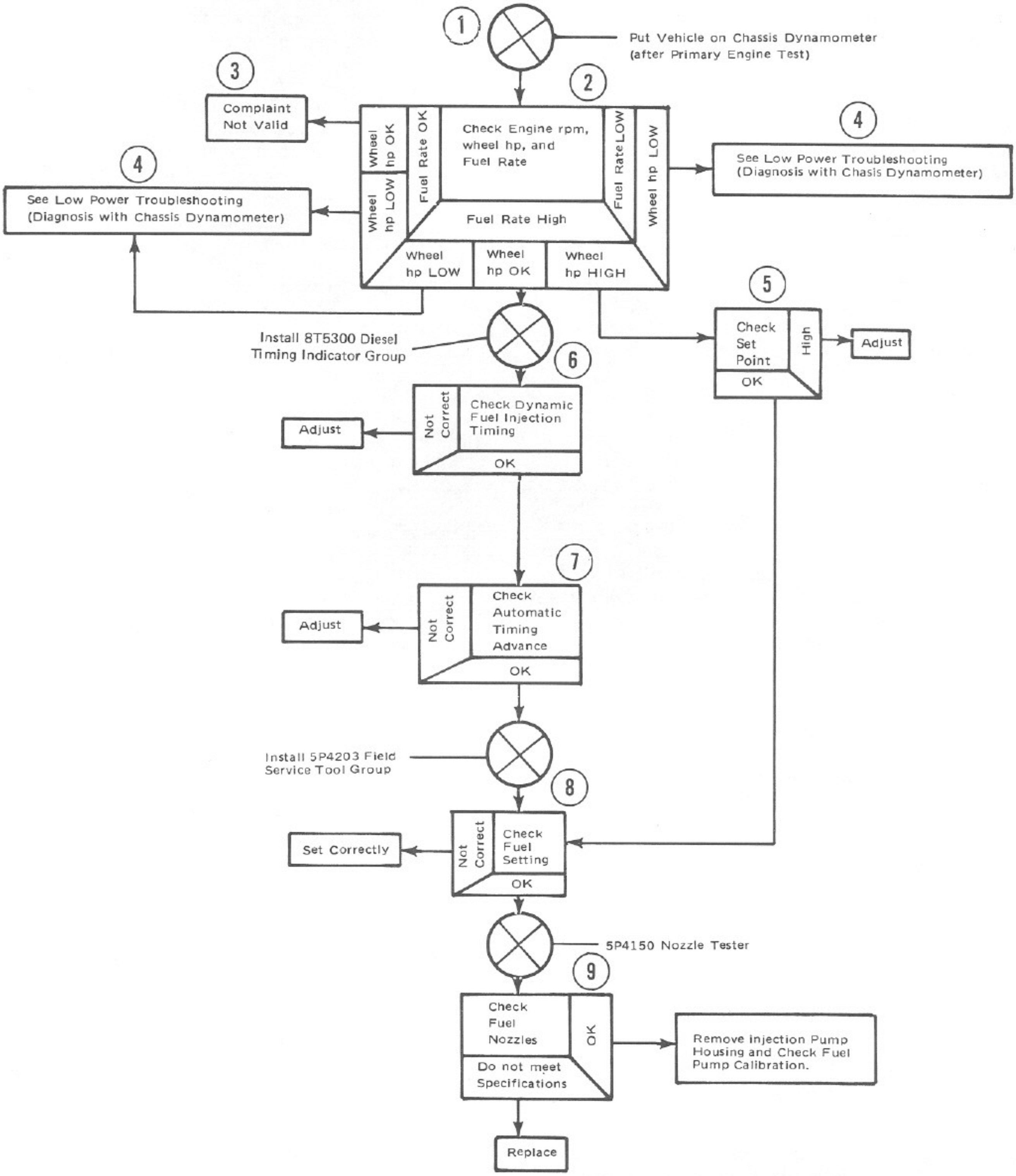
9. Install 5P4203 Field Service Tool Group, and check the fuel setting dimension. Compare the results with the dimensions given in the Fuel Setting and Related Information Fiche. If the fuel setting is correct, the vehicle will now have to be tested on a chassis dynamometer to determine the cause for high fuel consumption.

If the fuel setting is not correct, adjust to the setting given in the Fuel Setting and Related Information Fiche. Only a mechanic with the correct training should adjust the fuel setting. The procedure to check and adjust the fuel setting is in this Service Manual under the subject Fuel Setting.

10. If the test light still does not come on, this means that the fuel control shaft is not moving due to a problem inside the governor or a problem inside fuel injection pump housing. The governor should be checked for worn parts. The fuel injection pump housing should be checked for a worn fuel control shaft or its bore, or a fuel injection pump installed with sleeve not engaged with the lever on the fuel control shaft. The problem must be found and corrected.

HIGH FUEL CONSUMPTION

(Diagnosis with Chassis Dynamometer)


1
Put Vehicle on Chassis Dynamometer (after Primary Engine Test)
3
Complaint Not Valid
2
Check Engine rpm, wheel hp, and Fuel Rate
Wheel hp OK
Fuel Rate OK
Wheel hp LOW
Fuel Rate LOW
Wheel hp LOW
Fuel Rate High
Wheel hp LOW
Wheel hp OK
Wheel hp HIGH
4
See Low Power Troubleshooting (Diagnosis with Chassis Dynamometer)
4
See Low Power Troubleshooting (Diagnosis with Chasis Dynamometer)
5
Check Set Point
High
OK
Adjust
Install 8T5300 Diesel Timing Indicator Group
6
Check Dynamic Fuel Injection Timing
Not Correct
OK
Adjust
7
Check Automatic Timing Advance
Not Correct
OK
Adjust
Install 5P4203 Field Service Tool Group
8
Check Fuel Setting
Not Correct
OK
Set Correctly
5P4150 Nozzle Tester
9
Check Fuel Nozzles
OK
Do not meet Specifications
Remove injection Pump Housing and Check Fuel Pump Calibration.
Replace

High Fuel Consumption Troubleshooting

(Diagnosis with Chassis Dynamometer)

1. Preparation of vehicle for fuel consumption test (consult dynamometer manufacturer's operating instructions for specific details on correct operation).

NOTE: Always perform the Primary Engine Test procedure before vehicle is installed on chassis dynamometer.

a. Place vehicle on the chassis dynamometer. Tie the vehicle in a way that will not add any load to the drive wheels. Do not pull wheels down into dynamometer drive rolls.

Check the radiator coolant level, crankcase oil level, tire pressure, tire condition, remove rocks from the tire tread and connect exhaust system.

NOTICE

Recapped tires should be run on a chassis dynamometer only at the customer's own risk.

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b. The maximum acceptable fuel rate must be calculated for the customer's engine by use of the formula that follows:

$$\frac{1.03\ \text{bhp}\ (\text{BSFC} \pm .010)}{\text{Fuel Density (lbs/gal)}} = \text{Max. Fuel Rate}^{*}\ \text{(gal/hr)}$$

* At standard SAE test conditions

Find the rated brake specific fuel consumption (lb-bhp/hr) from the Fuel Setting And Related Information Fiche and add 0.25 mm (.010 in) manufacturing tolerance. Multiply this value by the advertised engine horsepower (plus 3% manufactures tolerance) and divide by the density of the fuel (lbs/gal).

c. Calculate the allowable limits that the customer can expect from his engine and present these figures to him. Caterpillar engines are rated with the conditions that follow:

Barometric pressure= 747 mm (29.4 in) of mercury
Inlet air temperature= 29°C (85°F) at air cleaner inlet
Fuel gravity= API gravity of 35 at 16°C (60°F)

Measure and record these variables.

2. Operate vehicle at 60% of rated speed with moderate load until oil and coolant temperatures reach their normal range for operation.

NOTICE

If there is a heavy vibration, drive shaft whip, tire bounce, etc., do not continue with dynamometer test until cause of the problem is corrected. Engines that have had new internal parts installed should be operated on a run-in schedule before operation at full load.

Put transmission in direct gear and the differential in the highest speed ratio. Operate vehicle at maximum engine speed and increase chassis dynamometer load until a speed of 50 rpm less than rated speed is reached (continuity light should be on). Maintain this speed for one minute and record the engine speed, wheel horsepower and fuel rate.

3. If the fuel rate and the wheel horsepower are both acceptable, then the engine is not the cause of the complaint, or the complaint is not valid. Refer to section Problem With Vehicle Or Vehicle Operation.

4. If the wheel horsepower is low, regardless of how the fuel rate measures, refer to the Low Power Troubleshooting Chart. The low power problem must be corrected first.

5. If the fuel rate and wheel horsepower are both too high, check the set point (balance point) of the engine (speed at which the load stop pin just touches the torque spring or stop bar). At this point the continuity light should flicker (go off and on dimly).

If the set point (balance point) is high, the high idle will have to be decreased to lower the set point (balance point) to the correct rpm (point at which the continuity light just comes on). If the set point (balance point) is correct, see Procedure No. 8.

6. If the fuel rate is high and the wheel horsepower is acceptable, use the 8T5300 Timing Indicator Group to check the timing of the fuel injection pump camshaft to the engine camshaft. See Fuel System of the Testing and Adjusting section of this Service Manual for the subject Checking Engine Timing And Automatic Timing Advance Unit With 8T5300 Timing Indicator Group. If the timing is correct, see Procedure No 7.

7. Use the 8T5300 Timing Indicator Group to check the automatic timing advance unit. Check to see that the advance is smooth and that the amount of advance is correct. See Fuel System of the Testing and Adjusting section of this Service Manual for the subject Checking Engine Timing And Automatic Timing Advance Unit With 8T5300 Timing Indicator Group.

8. If the fuel rate is still too high, install 5P4203 Field Service Tool Group and check the fuel setting. The correct fuel setting is given in Fuel Setting And Related Information Fiche. If fuel setting is not correct, the adjustment procedure is shown in Testing and Adjusting section of this Service Manual under subject Fuel Setting. If fuel setting is correct, see Procedure No 9.

9. Check the fuel nozzles with the 5P4150 Nozzle Tester. Testing of the injectors must be done off the engine. Use 5P4150 Nozzle Testing Group. For use of the 5P4150 Nozzle Testing Group, refer to Special Instruction, Form No. SEHS7292.

If the nozzles have been wire brushed or do not meet Caterpillar specifications, they must be replaced.

If the nozzles are good, remove the complete fuel injection pump housing and check the fuel pump calibration. See Fuel Pump Calibration in Testing and Adjusting section of this Service Manual.

Problem With Vehicle Or Vehicle Operation

PROBLEM WITH VEHICLE OR VEHICLE OPERATION

Probable Cause(s)

1. Tachometer Error
2. Engine Operated at High Altitude
3. Brakes Do Not Completely Release
4. Vehicle Operated in Too High a Gear
5. Extra Engine Driven Equipment
6. Speedometer Error
7. Speeds Too High
8. Overload on Vehicle
9. High Moving Resistance
10. High Wind Resistance
11. Power Loss in Drive Gears
12. Wrong Gear Ratios
13. Chassis Dynamometer Error
14. Trailers That are Difficult to Pull
15. High Inlet Air Temperature

The problems in this chart are problems that do come about and are normally called "low power." These problems are not necessarily more common than engine problems, but they are possible problems which you need to read and check before an engine is disassembled.

Read all of the items but make sure the first four are checked completely before making any engine test.

Problem With Vehicle Or Vehicle Operation

Recommended Procedure

1. Tachometer Error . . . To check, connect a tachometer of known accuracy to the engine. Run the engine and make a comparison of the readings of the vehicle and test tachometers. If vehicle tachometer is bad, make repairs as necessary or install a new tachometer.

2. Engine Operated at High Altitude . . . Less oxygen at higher altitudes causes the engine horsepower to go down. There is no effect on the 225 horsepower engine for the first 2280 m (7500 ft) above sea level of operation. There is no effect on the 235 and 250 horsepower engines for the first 1524 m (5000 ft) above sea level of operation. See the Fuel Setting And Related Information Fiche for the correct fuel setting for the higher altitude of operation.

3. Brakes Do Not Completely Release . . . Check the brakes by feeling all the brake drums. If the brakes of a wheel do not completely release, the brake drum for that wheel will be hotter than the brake drums for the other wheels. With the truck lifted with a jack, the wheels must have free rotation when turned by hand.

4. Vehicle Operated in Too High a Gear . . . If the operator does not shift the truck correctly, or operates the truck in a "lug" condition (using the truck in too high a gear for engine rpm to go up as accelerator pedal is pushed farther down, or using the truck in a gear where engine rpm goes down with accelerator pedal at maximum travel), poor vehicle performance is the result.

5. Extra Engine Driven Equipment . . . Air compressors, hydraulic pumps, alternators and other engine driven equipment that has damage, or that was not installed correctly, or that is not in correct adjustment can take more horsepower to drive than expected. If necessary, disconnect the equipment and test the engine.

6. Speedometer Error . . . A bad speedometer does not give the correct speed or the correct indication of fuel consumption. An indication of low speed can cause the operator to feel that he has a power problem.

7. Speeds Too High . . . The need for more horsepower is easy to see as the speed of the vehicle is increased. This is especially true if the front of the vehicle has a large surface area. Application personnel can give you the horsepower necessary for different vehicle designs at different speeds.

8. Overload on Vehicle . . . Application personnel can give you the horsepower needs for different vehicles.

9. High Moving Resistance . . . Soft ground conditions cause a need for more horsepower. To see if the problem is the engine, test the vehicle on a surface known to be good, or test on a chassis dynamometer.

10. High Wind Resistance . . . The horsepower needs for a truck can be divided into two parts. Part of the horsepower is used to move the vehicle and part is used to get through the resistance of the wind. The horsepower necessary to get through the resistance of the wind will increase as the vehicle is used at higher speeds. Vehicles with large front area have a higher wind resistance and take more horsepower than those with a small front area. Some types of trucks, for example, those used for the transportation of automobiles and/or boats have high wind resistance even if the front area is small. Moving against the wind has the same effect on wind resistance as does higher vehicle speed.

11. Power Loss in Drive Gears . . . It is possible for a transmission or rear axle to use extra horsepower because of damage, not being in correct adjustment, having the wrong type of fluid or not enough fluid in them, or an inside mechanical problem. If a part of the drive train unit operates at a higher temperature than normal, it can be the problem. Check this part of the drive train unit before working on any other part of the drive train unit. Powershift or automatic transmissions can cause the vehicle performance to be low if they are out of adjustment or not working correctly. See the transmission Service Manual for the correct adjustments.

12. Wrong Gear Ratios . . . The tire size, rear axle ratio, and transmission gear ratios must be correct to get maximum performance. If the transmission gear ratios are wrong, they can cause the engine rpm to go low enough during shifting that the engine can not have correct "acceleration" (increase in speed). A rear axle gear ratio which supplies too high a vehicle speed with the engine at a low rpm during normal vehicle operation, will cause the engine to be "lugging" (when the truck is used in a gear too high for engine rpm to go up as accelerator pedal is pushed farther down, or when the truck is used in a gear where engine rpm goes down with accelerator pedal at maximum travel). Application personnel can give you the correct tire sizes and gear ratios for your operation.

13. Chassis Dynamometer Error . . . Chassis dynamometers can be a great help in testing a vehicle for engine performance if they are in good condition and used correctly. When the dynamometer is not in good condition, or a bad operating procedure is used, the result will be wrong readings. For good comparison of horsepower readings from different vehicles, use the same dynamometer with the same operator.

14. Trailers That Are Difficult to Pull . . . Some trailers are more difficult to pull than others because of several factors. Some of these factors are: brakes not released completely, high wind resistance (because of a large front area and/or the design of the trailer), axles not in alignment, extra axles, and low tire pressure.

15. High Inlet Air Temperature . . . Air coming into the engine must be cool for the engine to have full horsepower. If the air inlet system is not of correct design or is not in good mechanical condition, hot air can come into the engine causing a loss of horsepower. To check the inlet air temperature, install the 8T0470 Thermistor Thermometer Group into the engine air inlet pipe.

Misfiring And Running Rough

MISFIRING AND RUNNING ROUGH

Probable Cause(s)

1. Air in Fuel System
2. Valve Adjustment Not Correct
3. Fuel Injection Timing Not Correct
4. Automatic Timing Advance Does Not Operate Correctly
5. Bad Fuel Nozzle(s)
6. Valve Leakage; Wear or Damage to Pistons and/or Piston Rings; Wear or Damage to Cylinder Walls
7. Cylinder Head Gasket Leakage
8. Engine Camshaft timing Not Correct
9. Fuel Leakage from Fuel Injection Line Nut
10. Fuel Has a High ''Cloud Point''

Misfiring And Running Rough

Recommended Procedure

1. Air in Fuel System . . . With air in the fuel system the engine will normally be difficult to start, run rough and release a large amount of white smoke. To remove the air from the fuel system, open the manual bleed valve on the fuel injection pump housing. Operate the priming pump until the flow of fuel from the manual bleed valve is free of air. Close the manual bleed valve and fasten the fuel priming pump. Start the engine. If the engine still does not run smooth or releases a large amount of white smoke, loosen the fuel line nuts one at a time at the cylinder heads, and permit the fuel to come out until it is free of air. Tighten the fuel line nuts. If air is not removed in this way, put 35 kPa (5 psi) of air pressure to the fuel tank.

NOTICE

Do not use more than 55 kPa (8 psi) of air pressure in the fuel tank or damage to the tank may result.

Check for leaks at the connections between the fuel tank and the fuel transfer pump. If leaks are found, tighten the connections or replace the lines. If there are no visual leaks, remove the fuel supply line from the tank and connect it to an outside fuel supply. If this corrects the problem, the suction line (standpipe) inside the fuel tank has a leak.

2. Valve Adjustment Not Correct . . . Check and make necessary adjustments as per Testing and Adjusting Section of this Service Manual. Intake valve clearance is 0.38 mm (.015 in) and exhaust valve clearance is 0.64 mm (.025 in). Also check for a bent or broken push rod.

3. Fuel Injection Timing Not Correct . . . Check and make necessary adjustments as per Testing and Adjusting Section of this Service Manual.

4. Automatic Timing Advance Does Not Operate Correctly . . . Check with engine warm. Use the 8T5300 Timing Indicator Group to check the automatic timing advance unit. Check to see that the advance is smooth and that the amount of advance is correct. See Fuel System of the Testing and Adjusting section of this Service Manual for the subject Checking Engine Timing And Automatic Timing Advance Unit With 8T5300 Timing Indicator Group. If the timing indicator is not available, make rapid "acceleration" (increase in speed) from low idle to high idle. Engine must have smooth acceleration.

   A timing advance that does not operate correctly can cause delays of the engine acceleration at some rpm before high idle, or possibly cause the engine to run rough and have exhaust noise (backfire) during acceleration. This condition is difficult to find if engine acceleration is slow or at a constant engine rpm.

5. Bad Fuel Nozzle(s) . . . Find a bad nozzle by running engine at the rpm where it runs rough. Loosen the fuel line nut at the cylinder head enough to stop fuel supply to that cylinder. Each cylinder must be checked this way. If a cylinder is found where loosening of the nut makes no difference in the rough running, test the nozzle for that cylinder. To test a nozzle, remove the nozzle from the engine and test.

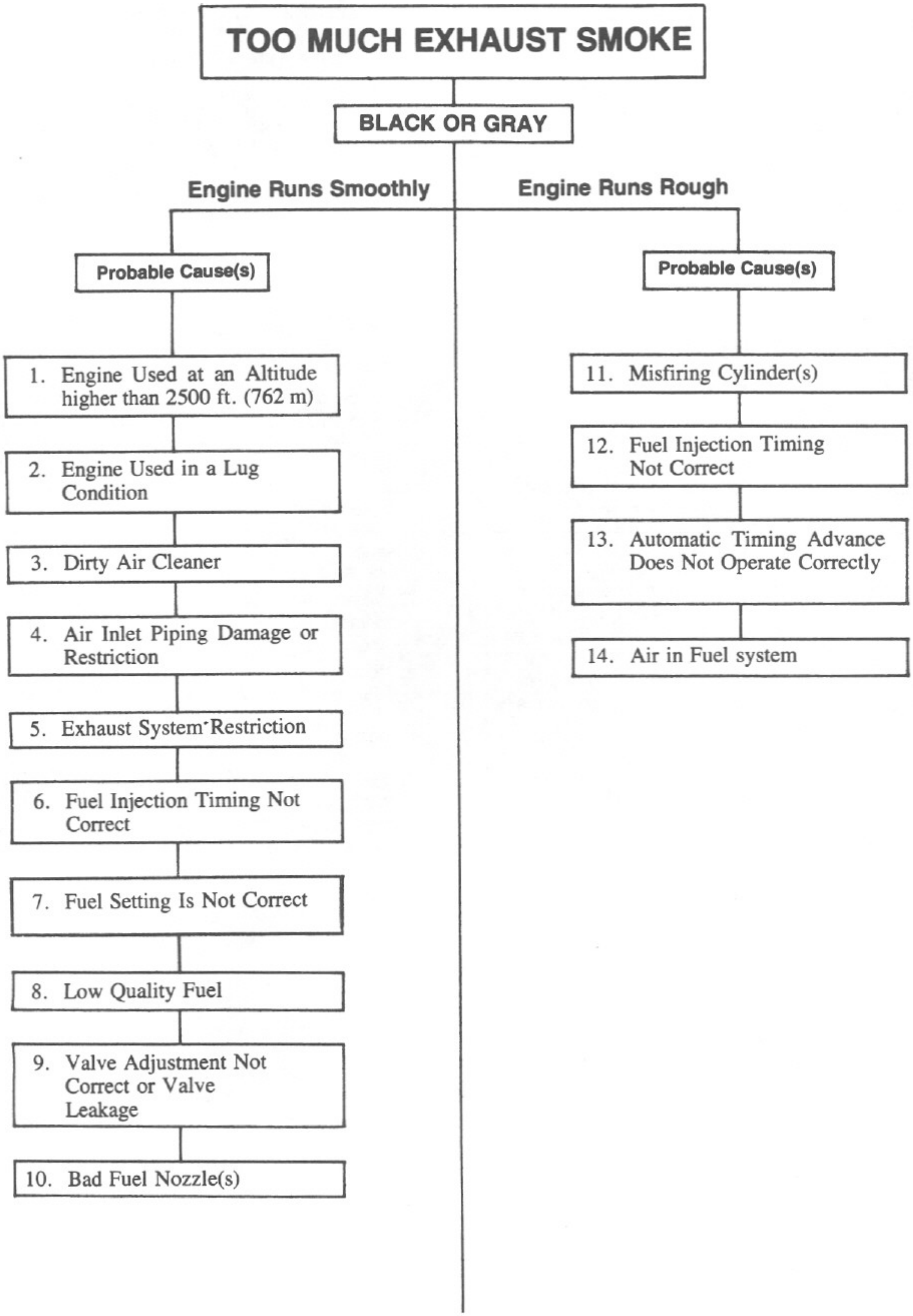
6. Valve Leakage; Wear or Damage to Pistons and/or Piston Rings; Wear or Damage to Cylinder Walls . . . The condition of these parts can be checked with a cylinder leakage tester. Special Instruction, Form No. GMG00694, gives the test procedure. The components can be bad if leakage is more than the specifications. If leakage is heard at the inlet manifold, the intake valves leak. If the leakage is heard at the exhaust manifold, the exhaust valves leak. If leakage is heard at the oil filler opening, the piston rings leak.

7. Cylinder Head Gasket Leakage . . . Check with the cylinder leakage tester. If leakage is higher than specifications, check at the fuel nozzle hole of the next cylinder to see if the leak is between cylinders. Leakage at the gasket of the cylinder head can show as an outside leak or can cause loss of coolant through the radiator overflow.

8. Engine Camshaft Timing Not Correct . . . Engine camshaft timing can be checked by finding the top center position for number one cylinder as per Testing and Adjusting section of this Service Manual. If timing is not correct remove the front cover and check timing marks. If timing marks are correct check for a broken drive dowel in the camshaft drive gear.

9. Fuel Leakage from Fuel Injection Line Nut . . . Tighten nut to 42 ± 7 N•m (31 ± 5 lb ft). Again check for leakage.

10. Fuel Has a High "Cloud Point" . . . The fuel "cloud point" is the temperature at which wax begins to form in the fuel. If the atmospheric temperature is lower than the "cloud point" of the fuel, wax will form and plug the filter. Change the filter and drain the tank and the complete fuel system. The replacement fuel must be of a better grade with a lower "cloud point".


TOO MUCH EXHAUST SMOKE
BLACK OR GRAY
Engine Runs Smoothly
Engine Runs Rough
Probable Cause(s)
Probable Cause(s)
1. Engine Used at an Altitude higher than 2500 ft. (762 m)
2. Engine Used in a Lug Condition
3. Dirty Air Cleaner
4. Air Inlet Piping Damage or Restriction
5. Exhaust System Restriction
6. Fuel Injection Timing Not Correct
7. Fuel Setting Is Not Correct
8. Low Quality Fuel
9. Valve Adjustment Not Correct or Valve Leakage
10. Bad Fuel Nozzle(s)
11. Misfiring Cylinder(s)
12. Fuel Injection Timing Not Correct
13. Automatic Timing Advance Does Not Operate Correctly
14. Air in Fuel system

Too Much Exhaust Smoke

Black or Gray

Engine Runs Smoothly

Recommended Procedure

1. Engine Used in a Lug Condition . . . "Lugging" (when the truck is used in a gear too high for engine rpm to go up as accelerator pedal is pushed farther down, or when the truck is used in a gear where engine rpm goes down with accelerator pedal at maximum travel) the engine causes a reduction in the intake of air with full fuel delivery to the cylinders. Because there is not enough air to burn all the fuel, the fuel that is not used comes out the exhaust as black smoke. To prevent lugging the engine, use a gear where engine can have "acceleration" (increase in speed) under load.

2. Dirty Air Cleaner . . . If the air cleaner has a restriction indicator, see if the red piston is in view. If there is no restriction indicator, restriction can be checked with a water manometer or a vacuum gauge (which measures in inches of water). Make a connection to the piping between the air cleaner and the inlet of the turbocharger. Check with the engine running at full load rpm. Maximum restriction is 635 mm (25 in) of water. If a gauge is not available, visually check the air cleaner element for dirt. If the element is dirty, clean the element or install a new element.

3. Air Inlet Piping Damage or Restriction . . . Make a visual inspection of the air inlet system and check for damage to piping, rags in the inlet piping, or damage to the rain cap or the cap pushed too far on the inlet pipe. If no damage is seen, check inlet restriction with a clean air cleaner element.

4. Exhaust System Restriction . . . Make a visual inspection of the exhaust system. Check for damage to piping or for a bad muffler. If no damage is found, you can check the system by checking the back pressure from the exhaust (pressure difference measurement between exhaust outlet and atmosphere). The back pressure must not be more than 1016 mm (40 in) of water. You can also check by removing the exhaust pipes from the exhaust manifolds. With the exhaust pipes removed, start and load the engine on a chassis dynamometer to see if the problem is corrected.

5. Fuel Injection Timing Not Correct . . . Check and make necessary adjustments as per Testing and Adjusting section of this Service Manual.

6. Fuel Setting is Not Correct . . . Check and make necessary adjustments as per Testing and Adjusting Section of this Service Manual. See the Fuel Setting And Related Information Fiche for the correct fuel setting.

7. Low Quality Fuel . . . Test the engine with fuel according to recommendations by Caterpillar.

8. Valve Adjustment Not Correct or Valve Leakage . . . Check and make necessary adjustments as per Testing and Adjusting section of this Service Manual. Intake valve clearance is 0.38 mm (.015 in) and exhaust valve clearance is 0.64 mm (0.25 in). Valve leakage normally causes the engine to "misfire" (injection not regular) and run rough. Valve leakage can be checked using the cylinder leakage tester. Special Instruction, Form No. GMG00694 gives the test procedure.

9. Bad Fuel Nozzles . . . Bad fuel nozzles will normally cause the engine to "misfire" (injection not regular) and run rough, but can cause too much smoke with engine still running smooth. Remove and test the fuel nozzles.

Engine Runs Rough

10. Misfiring Cylinder(s) . . . See Misfiring and Running Rough.

11. Fuel Injection Timing Not Correct. . .Check and make necessary adjustments as per Testing and Adjusting section of this Service Manual.

12. Automatic Timing Advance Does Not Operate Correctly . . . Check with engine warm. Use the 8T5300 Timing Indicator Group to check the automatic timing advance unit. Check to see that the advance is smooth and that the amount of advance is correct. See Fuel System of the Testing and Adjusting section of this Service Manual for the subject Checking Engine Timing And Automatic Timing Advance Unit With 8T5300 Timing Indicator Group. If the timing indicator is not available, make rapid "acceleration" (increase in speed) from low idle to high idle. Engine must have smooth acceleration. A timing advance that does not operate correctly can cause delays of the engine acceleration at some rpm before high idle, or possibly cause the engine to run rough and have exhaust noise (backfire) during acceleration. This condition is difficult to find if engine acceleration is slow or at a constant engine rpm.

13. Air in Fuel System . . . With air in the fuel system the engine will normally be difficult to start, run rough and release a large amount of white smoke. To remove the air from the fuel system open the manual bleed valve on the fuel injection pump housing. Operate the priming pump until the flow of fuel from the manual bleed valve is free of air. Close the manual bleed valve and fasten the fuel priming pump. Start the engine. If the engine still does not run smooth or releases a large amount of white smoke, loosen the fuel line nuts one at a time at the cylinder heads, and permit the fuel to come out until it is free of air. Tighten the fuel line nuts. If air is not removed in this way, put 35 kPa (5 psi) of air pressure to the fuel tank.

NOTICE

Do not use more than 55 kPa (8 psi) of air pressure in the fuel tank or damage to the tank may result.

Check for leakage at the connections between the fuel tank and the fuel transfer pump. If leaks are found, tighten the connections or replace the lines. If there are no visual leaks, remove the fuel supply line from the tank and connect it to an outside fuel supply. If this corrects the problem, the suction line (standpipe) inside the fuel tank has a leak.

Too Much Exhaust Smoke

White Smoke
Blue Smoke

TOO MUCH EXHAUST SMOKE

Probable Cause(s)

White Smoke

1. Cold Outside Temperatures
2. Long Idle Periods
3. Low Quality Fuel
4. Air in Fuel System
5. Fuel Injection Timing Not Correct
6. Automatic Timing Advance Does Not Operate Correctly
7. Valve Adjustment Not Correct
8. Bad Fuel Nozzles(s)
9. Misfiring Cylinder(s)

Blue Smoke

10. Oil Level in Engine Too High
11. Damage to Positive Crankcase Ventilator Valve or Valve Assembled Wrong
12. Worn Valve Guides
13. Worn Piston Rings and/or Cylinder Walls
14. Wear or Damage to Pistons

Too Much Exhaust Smoke

White Smoke

Recommended Procedure

1. Cold Outside Temperatures . . . When the air outside is cold, the cylinder temperature is cooler. Not all the fuel will burn in the cylinders. The fuel which does not burn comes out the exhaust as white smoke. White smoke is normal in cold temperatures until the engine operates long enough to become warm. There will be less white smoke if No. 1 diesel fuel is used.

2. Long Idle Periods . . . When an engine runs at idle speed for a long period of time, the cylinders cool and all of the fuel does not burn. Do not idle an engine for a long period of time. Stop an engine when it is not in use. If long idle periods are necessary, use No. 1 diesel fuel.

3. Low Quality Fuel . . . Test the engine using fuel according to recommendations by Caterpillar.

4. Air in Fuel System . . . With air in the fuel system the engine will normally be difficult to start, run rough and release a large amount of white smoke. To remove the air from the fuel system open the manual bleed valve on the fuel injection pump housing. Operate the priming pump until the flow of fuel from the manual bleed valve is free of air. Close the manual bleed valve and fasten the fuel priming pump. Start the engine. If the engine still does not run smooth or releases a large amount of white smoke, loosen the fuel line nuts one at a time at the cylinder heads, and permit the fuel to come out until it is free of air. Tighten the fuel line nuts. If air is not removed in this way, put 35 kPa (5 psi) of air pressure to the fuel tank.

NOTICE

Do not use more than 55 kPa (8 psi) of air pressure in the fuel tank or damage to the tank may result.

Check for leakage at the connections between the fuel tank and the fuel transfer pump. If leaks are found, tighten the connections or replace the lines. If there are no visual leaks, remove the fuel supply line from the tank and connect it to an outside fuel supply. If this corrects the problem, the suction line (standpipe) inside the fuel tank has a leak.

5. Fuel Injection Timing Not Correct . . . Check and make necessary adjustments as per Testing and Adjusting section of this Service Manual.

6. Automatic Timing Advance Does Not Operate Correctly . . . Check with engine warm. Use the 8T5300 Timing Indicator Group to check the automatic timing advance unit. Check to see that the advance is smooth and that the amount of advance is correct. See Fuel System of the Testing and Adjusting section of this Service Manual for the subject Checking Engine Timing And Automatic Timing Advance Unit With 8T5300 Timing Indicator Group. If the timing indicator is not available, make rapid "acceleration" (increase in speed) from low idle to high idle. Engine must have smooth acceleration. A timing advance that does not operate correctly can cause delays of the engine acceleration at some rpm before high idle, or possibly cause the engine to run rough and have exhaust noise (backfire) during acceleration. This condition is difficult to find if engine acceleration is slow or at a constant engine rpm.

7. Valve Adjustment Not Correct . . . Check and make necessary adjustments as per Testing and Adjusting section of this Service Manual. Intake valve clearance is 0.38 mm (.015 in) and exhaust valve clearance is 0.64 mm (.025 in).

8. Bad Fuel Nozzles(s) . . . Bad Fuel nozzles will normally cause the engine to "misfire" (injection not regular) and run rough, but can cause too much smoke and the engine still be running smooth. Remove and test the fuel nozzles.

9. Misfiring Cylinder(s) . . . See Misfiring and Running Rough.

Blue Smoke

10. Engine Oil Level Too High . . . Do not put too much oil in the crankcase. If the oil level in the crankcase goes up as the engine is used, check for fuel in the crankcase. See Fuel In Crankcase Oil.

11. Damage to Positive Crankcase Ventilator Valve or Valve Assembled Wrong . . . The positive crankcase ventilator valve must be assembled correctly and the diaphragm and/or gasket must be free of damage.

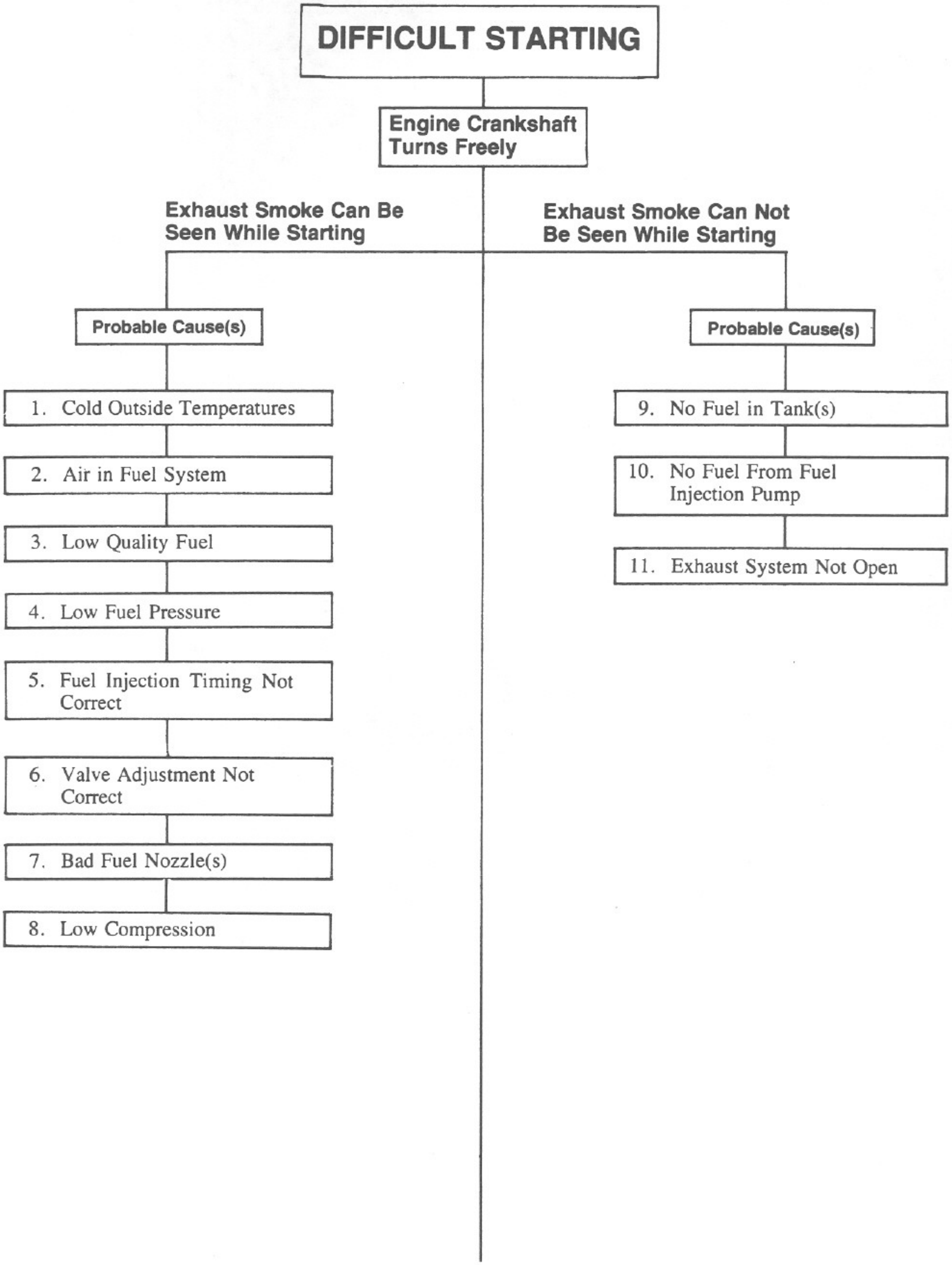
12. Worn Valve Guides . . . See the Specifications section of this Service Manual for the maximum permissible wear of the valve guides. The repair procedure for valve guides is in the Reconditioning Procedures section of this Service Manual.

13. Worn Piston Rings and/or Cylinder Walls . . . Worn piston rings and/or cylinder walls can be the cause of blue smoke and can cause a loss of compression. Check cylinder condition with the cylinder leakage tester. Special Instruction, Form No. GMG00694, gives the test procedure. Make a visual inspection of the cylinder walls and piston rings. If necessary measure the cylinder walls and piston rings. For the cylinder and piston ring specifications see the Specification section of this Service Manual. NOTE: High wear at low mileage is normally caused by dirt coming into the engine with the inlet air.

14. Wear or Damage to Pistons . . . Check piston ring to groove clearance. Pistons which have worn grooves and pistons with damage or defects can cause blue smoke and too much oil consumption. Make sure the oil return holes under the oil ring are open.

Difficult Starting

Engine Crankshaft Turns Freely



DIFFICULT STARTING

Engine Crankshaft Turns Freely

Exhaust Smoke Can Be Seen While Starting

Probable Cause(s)

1. Cold Outside Temperatures
2. Air in Fuel System
3. Low Quality Fuel
4. Low Fuel Pressure
5. Fuel Injection Timing Not Correct
6. Valve Adjustment Not Correct
7. Bad Fuel Nozzle(s)
8. Low Compression

Exhaust Smoke Can Not Be Seen While Starting

Probable Cause(s)

9. No Fuel in Tank(s)
10. No Fuel From Fuel Injection Pump
11. Exhaust System Not Open

Difficult Starting

Engine Crankshaft Turns Freely

Exhaust Smoke Can Be Seen While Starting

Recommended Procedure

1. Cold Outside Temperatures . . . It may be necessary to use starting aids, or to heat engine oil or coolant at temperatures below 10°C (50°F).

2. Air in Fuel System . . . With air in the fuel system the engine will normally be difficult to start, run rough and release a large amount of white smoke. To remove the air from the fuel system, open the manual bleed valve on the fuel injection pump housing. Operate the priming pump until the flow of fuel from the manual bleed valve is free of air. Close the manual bleed valve and fasten the fuel priming pump. Start the engine. If the engine still does not run smooth or releases a large amount of white smoke, loosen the fuel line nuts one at a time at the cylinder heads, and permit the fuel to come out until it is free of air. Tighten the fuel line nuts. If air is not removed in this way, put 35 kPa (5 psi) of air pressure to the fuel tank.

NOTICE

Do not use more than 55 kPa (8 psi) of air pressure in the fuel tank or damage to the tank may result.

Check for leakage at the connections between the fuel tank and the fuel transfer pump. If leaks are found, tighten the connections or replace the lines. If there are no visual leaks, remove the fuel supply line from the tank and connect it to an outside fuel supply. If this corrects the problem, the suction line (standpipe) inside the fuel tank has a leak.

3. Low Quality Fuel . . . Remove a small amount of fuel from the tank and check for water in the fuel. If there is water in the fuel, remove fuel from the tank until it is free of water and fill with a good quality fuel. Change the fuel filter and "prime" (remove the air and/or low quality fuel from the fuel system) the fuel system with the fuel priming pump. If there is no water in the fuel, prime and start the engine by using an outside source of fuel. If engine starts correctly using different fuel, remove all fuel from the tank and fill with good quality fuel. Prime the fuel system if necessary.

4. Low Fuel Pressure . . . Change the fuel filter. If the pressure is still low, check the bypass valve in the fuel transfer pump. Debris in the system can make the valve become stationary in the open position.

5. Fuel Injection Timing Not Correct . . . Check and make necessary adjustments as per Testing and Adjusting section of this Service Manual.

6. Valve Adjustment Not Correct . . . Check and make necessary adjustments as per Testing and Adjusting section of this Service Manual. Intake valve clearance is 0.38 mm (.015 in) and exhaust valve clearance is 0.64 mm (.025 in).

7. Bad Fuel Nozzle(s) . . . Remove and test the fuel nozzles.

8. Low Compression . . . See Misfiring and Running Rough.

Exhaust Smoke Can Not Be Seen While Starting

9. No Fuel in Tank(s) . . . Check fuel level visually (do not use the fuel gauge only). Be sure tank selection valve is open to the tank with fuel in it. Be sure valve in fuel line between the tanks is open.

10. No Fuel From Fuel Injection Pump . . . Loosen a fuel injection line nut at the pump housing. With ignition switch in the ON position and accelerator in the FUEL ON position, turn the engine with the starter to be sure there is no fuel from the fuel injection pump. To find the cause for no fuel, follow Steps (a) through (d) until the problem is corrected.

a. Prime the fuel system as shown in Procedure No. 2.

b. Check shutoff solenoid by turning ignition switch to ON position. You must hear a sound when the plunger opens. If no sound is heard, make sure there is battery voltage at the solenoid. If the solenoid does not work, install a new solenoid.

c. If you are not using a good quality of fuel at temperatures below −12°C (10°F), it is possible that the fuel in the system can "wax" (not have correct flow characteristics) and cause a restriction in the fuel system. Install a new fuel filter. It may be necessary to drain the complete fuel system and replace with a No. 1 grade of fuel.

d. Check for fuel supply line restriction by removing the fuel supply line for the fuel filter base. Put 35 kPa (5 psi) of air pressure to the fuel tank.

NOTICE

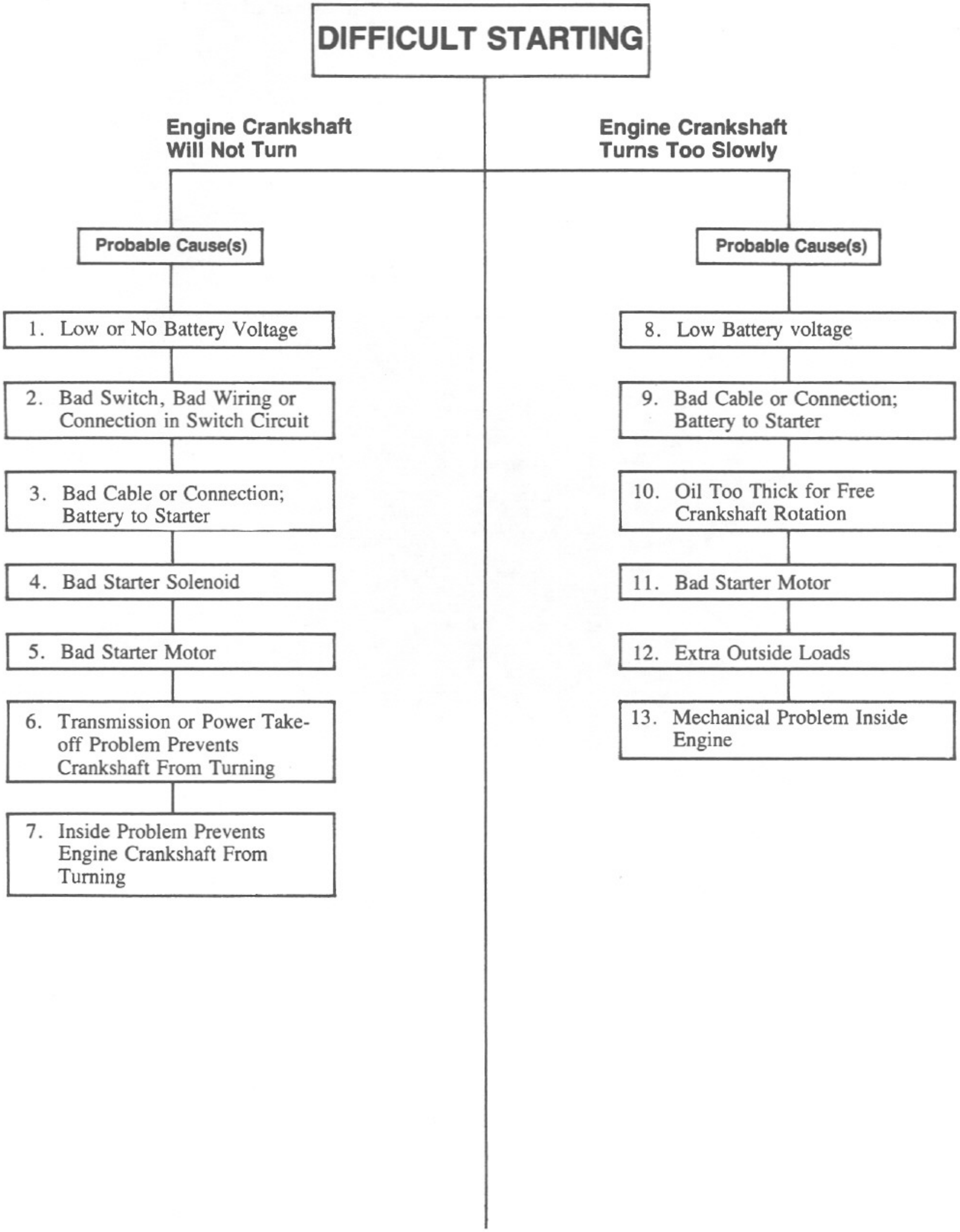
Do not use more than 55 kPa (8 psi) of air pressure in the fuel tank or damage to the tank may result.

If there is no fuel, or only a weak flow of fuel from the fuel supply line, there is a restriction in the fuel supply line and/or the fuel tank.

11. Exhaust System Not Open . . . Loosen the exhaust pipe from the exhaust manifold. If engine will now start, check the exhaust system for damage and/or restrictions.

Difficult Starting

Engine Crankshaft Will Not Turn
Engine Crankshaft Turns Too Slowly


DIFFICULT STARTING
Engine Crankshaft Will Not Turn
Engine Crankshaft Turns Too Slowly
Probable Cause(s)
1. Low or No Battery Voltage
2. Bad Switch, Bad Wiring or Connection in Switch Circuit
3. Bad Cable or Connection; Battery to Starter
4. Bad Starter Solenoid
5. Bad Starter Motor
6. Transmission or Power Take-off Problem Prevents Crankshaft From Turning
7. Inside Problem Prevents Engine Crankshaft From Turning
Probable Cause(s)
8. Low Battery voltage
9. Bad Cable or Connection; Battery to Starter
10. Oil Too Thick for Free Crankshaft Rotation
11. Bad Starter Motor
12. Extra Outside Loads
13. Mechanical Problem Inside Engine

Difficult Starting

Engine Crankshaft Will Not Turn

Recommended Procedure

1. Low or No Battery Voltage . . . Check battery voltage. If battery voltage is less than 8 volts for a 12 volt system, or 16 volts for a 24 volt system, put a charge to the battery. If battery will not hold a charge, load test the battery as shown in the Electrical System of the Testing and Adjusting section of this Service Manual.

2. Bad Switch, Bad Wiring or Connection in Switch Circuit . . . With ignition switch in START position, check voltage at switch connection on starter solenoid. If there is no voltage, or if the voltage is low at this connection, check wiring, connections, ignition switch, and magnetic switch (if used).

3. Bad Cable or Connection; Battery to Starter . . . With ignition switch in the START position, check voltage at connection of battery cable to starter. If there is no voltage, or if the voltage is low at this connection and there is good voltage at the battery, check for bad cable or connection between the battery and the starter.

4. Bad Starter Solenoid . . . Remove and repair a solenoid which does not work when voltage is correct at both the battery and ignition switch connections.

5. Bad Starter Motor . . . If the solenoid works and the starter motor does not turn the crankshaft, the starter motor is bad. Before removing the starter motor, turn the crankshaft by hand to be sure a mechanical failure inside the engine, transmission, or power take-off is not preventing the crankshaft from turning. If crankshaft turns freely by hand, engage the starter motor again. If the starter motor still will not work, remove the starter motor and repair it, or install a new starter motor.

6. Transmission or Power Take-off (if so equipped) Problem Prevents Crankshaft From Turning . . . If crankshaft can not be turned by hand, disconnect the transmission and power take-off. If crankshaft will now turn, find the cause of the problem in the transmission or power take-off and make necessary corrections.

7. Inside Problem Prevents Engine Crankshaft From Turning . . . If the crankshaft can not be turned after disconnecting the transmission and power take-off, remove the fuel nozzles and check for fluid in the cylinders while turning the crankshaft. If fluid in the cylinders is not the problem, the engine must be disassembled to check for other inside problems. Some of these inside problems are bearing seizure, piston seizure, and valves making contact with pistons.

Engine Crankshaft Turns Too Slowly

8. Low Battery Voltage . . . Check battery voltage. If battery voltage is less than 8 volts for a 12 volt system, or 16 volts for a 24 volt system, put a charge to the battery. If the battery will not hold a charge, load test the battery as shown in the Electrical System of the Testing and Adjusting section of this Service Manual.

9. Bad Cable or Connection; Battery to Starter . . . With switch in START position, check voltage at battery cable connection to starter. If voltage is low at this connection and there is good voltage at the battery, check for bad cable or connection between the battery and the starter.

10. Oil Too Thick for Free Crankshaft Rotation . . . Use recommended Lubricant Viscosities as found in the Operation And Maintenance Guide.

11. Bad Starter Motor . . . Remove and test. Make repairs as necessary or install a new starter motor.

12. Extra Outside Loads . . . Damage to the power take-off equipment (if so equipped) and/or transmission can put extra load on the engine. This prevents free rotation of the crankshaft. To check, disconnect the transmission and power take-off, and start the engine.

13. Mechanical Problem Inside Engine . . . Take the engine apart and check all components for damage.

COOLING SYSTEM

Above Normal Heating

Probable Cause(s)

1. Low Coolant Level
2. Bad Temperature Gauge
3. Dirty Radiator
4. Loose Belt(s)
5. Bad Hose(s)
6. Shunt Line Restriction
7. Shutters Not Opening Correctly
8. Bad Water Temperature Regulators
9. Bad Water Pump
10. Air in Cooling System
11. Wrong Fan, Fan or Shroud Not in Correct Position
12. Radiator Too small
13. Not Enough Air Flow Through Radiator Because of Restriction in Engine Compartment
14. High Outside Temperature

Above Normal Heating (Cont.)

Probable Cause(s)

15. Operation at High Altitude
16. Engine Used in a Lug Condition
17. Air Inlet Restriction
18. Exhaust Restriction
19. Fuel Injection Timing Not Correct
20. Transmission Problems

Below Normal Heating

Probable Cause(s)

21. Long Idle Periods
22. Very Light Load
23. Bad Water Temperature Regulator(s) and/or Vent Valve

Cooling System

Above Normal Heating

Recommended Procedure

1. Low Coolant Level . . . If the coolant level is too low, not enough coolant will go through the engine and radiator. This lack of coolant will not take enough heat from the engine and there will not be enough flow of coolant through the radiator to release the heat into the cooling air. Low coolant level is caused by leaks or wrong filling of the radiator. With the engine cool, be sure that coolant can be seen at the low end of the fill neck on the radiator top tank.

2. Bad Temperature Gauge . . . A temperature gauge which does not work correctly will not show the correct temperature. If the temperature gauge shows that the coolant temperature is too hot but other conditions are normal, either install a gauge you know is good or check the cooling system with the 8T0470 Thermistor Thermometer Group.

3. Dirty Radiator . . . Check the radiator for debris between the fins of the radiator core which prevents free air flow through the radiator core. Check the radiator for debris, dirt, or deposits on the inside of the radiator core which prevents free flow of coolant through the radiator.

4. Loose Belt(s) . . . Loose fan belts will cause a reduction in air flow. Tighten the belts according to V-Belt Tension Chart that is shown in Specification section of this Service Manual.

5. Bad Hose(s) . . . Bad hoses with leaks can normally be seen. Hoses that have no visual leaks can "collapse" (pull together) during operation and cause a restriction in the flow of coolant. Hoses become soft and/or get cracks after a period of time. Hoses must be changed after 50,000 miles or a year of use. The inside of a hose can deterioriate, and the loose particles of the hose can cause a restriction in the flow of coolant.

6. Shunt Line Restriction . . . A restriction of the shunt line from the radiator top tank to the engine water pump inlet, or a shunt line not installed correctly, will cause a reduction in water pump efficiency. The result will be low coolant flow and overheating.

7. Shutters Not Opening Correctly . . . Check the opening temperature of the shutters. The shutters must be completely closed at a temperature below the fully open temperature of the water temperature regulators.

8. Bad Water Temperature Regulator(s) . . . A regulator that does not open, or only opens part of the way, can cause above normal heating. To test the thermostats, see the Testing and Adjusting section of this Service Manual.

9. Bad Water Pump . . . A water pump with a loose or damaged impeller does not pump enough coolant for correct engine cooling. Remove the water pump and check for damage to the impeller. If the impeller has no damage, check the impeller clearance. The clearance between the impeller and the housing is 0.28 to 0.84 mm (.011 to .033 in).

10. Air in Cooling System . . . Air can get into the cooling system in different ways. The most common causes are not filling the cooling system correctly, and combustion gas leaking into the system. Combustion gas can get into the system through inside cracks or bad cylinder head gaskets. Air in the cooling system causes a reduction in coolant flow and bubbles in the coolant. Air bubbles hold coolant away from engine parts, preventing heat flow.

Air in the cooling system can be found by the Bottle Test. The equipment needed to make this test is a one pint bottle, a bucket of water and a hose which will fit the end of the overflow pipe of the radiator.

Before testing, make sure the cooling system is filled correctly. Use a wire to hold the relief valve in the radiator cap open. Install the radiator cap and tighten it. Put the hose over the end of the overflow pipe.

Start the engine and operate it at high idle rpm for a minimum of five minutes after the engine is at normal operating temperature. Use a cover on the radiator core to keep the engine at operating temperature. After five or more minutes at operating temperature, place the loose end of the hose in the bottle filled with water. Put the bottle in the bucket of water with the top down. If the water gets out of the bottle in less than forty seconds, there is too much exhaust gas leakage into the cooling system. Find the cause of the air or gas getting into the cooling system and correct as necessary.

11. Wrong Fan, Fan or Shroud Not in Correct Position . . . A wrong fan, or a fan or shroud in a wrong position will cause a reduction or a loss of air flow through the radiator. The fan must be large enough to send air through most of the area of the radiator core. Make sure the fan size, fan shroud and position of fan and shroud are according to the recommendations of the Truck Manufacturer.

12. Radiator Too Small . . . A radiator which is too small does not have enough area to release the heat to the cooling air. This will cause the engine to run at higher than normal temperatures. Make sure the radiator size is according to the recommendations of the Truck Manufacturer.

13. Not Enough Air Flow Through Radiator Because of Restriction in Engine Compartment . . . The air flow through the radiator comes out of the engine compartment. Make sure the filters, air conditioners and similar items are not installed in a way which prevents free flow of air into and out of the engine compartment.

14. High Outside Temperature . . . When outside temperatures are too high for the rating of the cooling system, there is not enough temperature difference between the outside air and coolant temperatures. To get better cooling, use the truck in a lower gear.

15. Operation at High Altitude . . . The cooling capacity of the cooling system goes down as the truck is used at higher altitudes. A system, under pressure, large enough to keep the coolant from boiling must be used.

16. Engine Used in a Lug Condition . . . "Lugging" (when the truck is used in a gear too high for engine rpm to go up as accelerator pedal is pushed farther down, or when the truck is used in a gear where engine rpm goes down with accelerator pedal at maximum travel) the engine causes the engine rpm and fan rpm to be low. This low rpm causes a reduction in air flow through the radiator, and a reduction in the flow of coolant through the system. This combination of less air and less coolant flow during high input of fuel will cause above normal heating.

17. Air Inlet Restriction . . . Restriction of the air coming into the engine causes high cylinder temperatures and more than normal amount of heat to pass to the cooling system. Check for a restriction with a water manometer or a vacuum gauge (which measures in inches of water). Connect the gauge to the engine air inlet between the air cleaner and the inlet to the turbocharger. With gauge installed, run engine at full load rpm and check the restriction. Maximum restriction of air inlet is 635 mm (25 in) of water. If the indication is higher than the maximum permissible restriction, remove the dirt from the filter element, or install a new filter element and check the restriction again. If the indication is still too high, there must be a restriction in the inlet piping.

18. Exhaust Restriction . . . Restriction in the exhaust system causes high cylinder temperatures and more than normal amount of heat to pass to the cooling system. To see if there is an exhaust restriction, make a visual inspection of the exhaust system. Check for damage to piping or for a bad muffler. If no damage is found, check the system for back pressure from the exhaust (pressure difference measurement between exhaust outlet and atmosphere). The back pressure must not be more than 1016 mm (40 in) of water. You can also check the system by removing the exhaust pipes from the exhaust manifolds. With the exhaust pipes removed, start and run the engine to see if the problem is corrected.

19. Fuel Injection Timing Not Correct . . . Check and make necessary adjustments as per Testing and Adjusting section of this Service Manual.

20. Transmission Problems . . . Power-shift or automatic transmissions that are cooled by the engine cooling system can cause above normal heating if they are out of adjustment or not working correctly. See the transmission Service Manual for the correct adjustments.

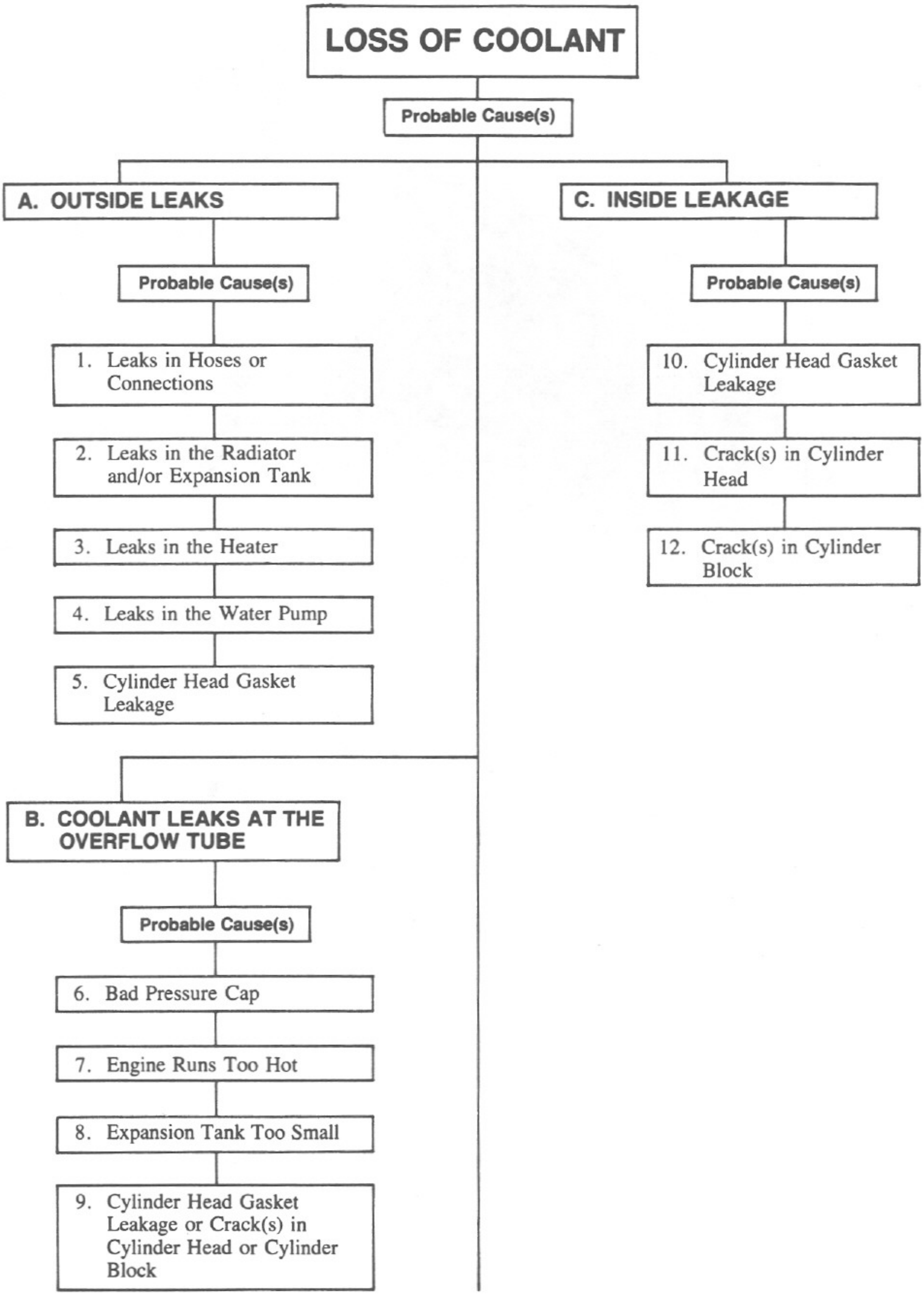
Below Normal Heating

21. Long Idle Periods . . . When the engine is running with no load, only a small quantity of fuel is burnt and engine heat is removed too fast.

22. Very Light Load . . . Very light loads, and a very slow speed or downhill travel can cause below normal heating because of the low heat input of the engine. The installation of shutters helps to correct this condition.

23. Bad Water Temperature Regulator(s) and/or vent valve . . . A regulator that is "stuck" open (will not move to the closed position) will cause below normal heating. A regulator that is stuck between the open and closed positions, or a vent valve that is stuck open, can cause below normal heating when the truck has a light load.

Loss Of Coolant


LOSS OF COOLANT
Probable Cause(s)
A. OUTSIDE LEAKS
Probable Cause(s)
1. Leaks in Hoses or Connections
2. Leaks in the Radiator and/or Expansion Tank
3. Leaks in the Heater
4. Leaks in the Water Pump
5. Cylinder Head Gasket Leakage
B. COOLANT LEAKS AT THE OVERFLOW TUBE
Probable Cause(s)
6. Bad Pressure Cap
7. Engine Runs Too Hot
8. Expansion Tank Too Small
9. Cylinder Head Gasket Leakage or Crack(s) in Cylinder Head or Cylinder Block
C. INSIDE LEAKAGE
Probable Cause(s)
10. Cylinder Head Gasket Leakage
11. Crack(s) in Cylinder Head
12. Crack(s) in Cylinder Block

Loss of Coolant

Recommended Procedure

A. **Outside Leaks**

1. Leaks in Hoses or Connections . . . Check all hoses and connections for visual signs of leakage. If no leaks are seen, look for damage to hoses or loose clamps.

2. Leaks in the Radiator and/or Expansion Tank . . . Put pressure to the radiator and/or expansion tank with the 9S8140 Cooling System Pressurizing Pump Group and check for leaks.

3. Leaks in the Heater . . . Put pressure to the cooling system with the 9S8140 Cooling System pressurizing Pump Group and check the heater for leaks.

4. Leaks in the Water Pump . . . Check the water pump for leaks before starting the engine, then start the engine and look for leaks. If there are leaks at the water pump, repair or install a new water pump.

5. Cylinder Head Gasket Leakage . . . Look for leaks along the surface of the cylinder head gasket. If you see leaks, install a new head gasket.

B. **Coolant Leaks at the Overflow Tube**

6. Bad Pressure Cap or Relief Valve . . . Check the sealing surfaces of the pressure cap and the radiator to be sure the cap is sealing correctly. Check the opening pressure and sealing ability of the pressure cap or relief valve with the 9S8140 Cooling System Pressurizing Pump Group.

7. Engine Runs Too Hot . . . If coolant temperature is too high, pressure will be high enough to move the cap off of the sealing surface in the radiator and cause coolant loss through the overflow tube. See "Above Normal Heating" in COOLING SYSTEM Chart.

8. Expansion Tank Too Small or Installed Wrong . . . The expansion tank can be either a part of the radiator or it can be installed separately from the radiator. The expansion tank must be large enough to hold the expansion of the coolant as it gets warm or has sudden changes in pressure. Make sure the expansion tank is installed correctly, and the size is according to the recommendations of the Truck Manufacturer.

9. Cylinder Head Gasket Leakage, or Crack(s) in Cylinder Head or Cylinder Block . . . Remove the radiator cap and with the engine running look for air bubbles in the coolant. Bubbles in the coolant are a sign of probable leakage at the head gasket. With the engine not running, check each cylinder with the cylinder leakage tester. Special Instruction, Form No. GMG00694 gives the test procedure. If you see air bubbles in the coolant during this test, there is a leak of combustion gas into the cooling system. Remove the cylinder heads from the engine. Check cylinder heads, cylinder walls and head gasket surface of the cylinder block for cracks. When installing heads, use new head gasket.

C. **Inside Leakage**

10. Cylinder Head Gasket Leakage . . . If the cylinder head gasket leaks between a water passage and an opening into the crankcase, coolant will get into the crankcase.

11. Crack(s) in Cylinder Head . . . Crack(s) in the upper surface of the cylinder head, or an area between a water passage and an opening into the crankcase, can allow coolant to get into the crankcase.

12. Crack(s) in Cylinder Block . . . Crack(s) in the cylinder block between a water passage and the crankcase will let coolant get into the crankcase.

FUEL IN CRANKCASE OIL

Probable Cause(s)

1. Bad Seals on Fuel Injection Pump Camshaft and/or the Drain Line from the Bottom of the Fuel Transfer Pump has a Restriction
2. Loose Fuel Injection Nozzle Nut
3. Bad Fuel Nozzle(s)

Fuel in Crankcase Oil

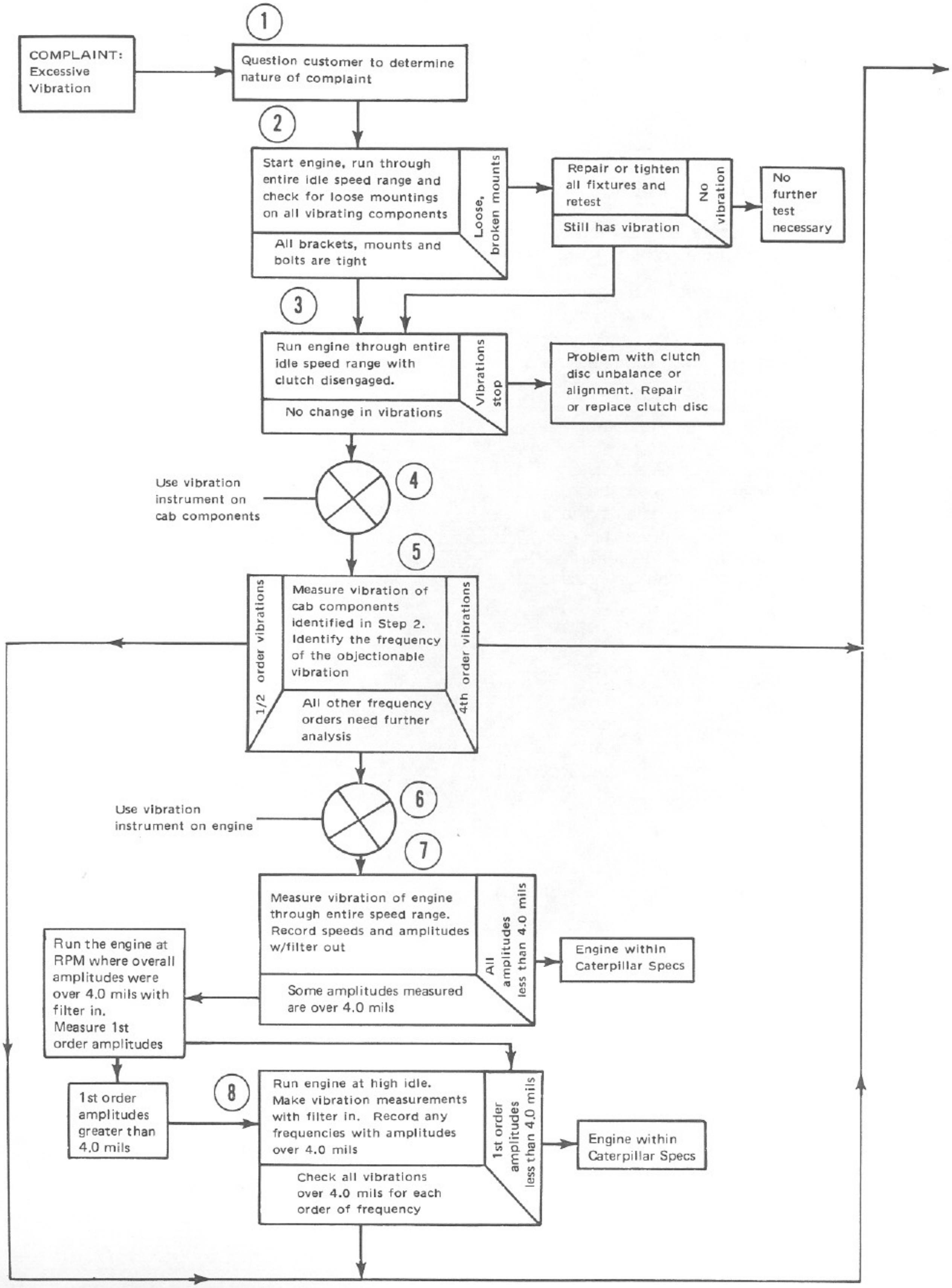
Recommended Procedure

1. Bad Seals on Fuel Injection Pump Camshaft and/or the Drain Line from the bottom of the Fuel Transfer Pump has a Restriction . . . If both seals on the fuel pump camshaft in the body for the fuel transfer pump and/or the drain line from the bottom of the fuel transfer pump has a restriction the fuel can leak by the seals directly into the engine. To correct, install new seals in the body for the fuel transfer pump and be sure the drain line is open.

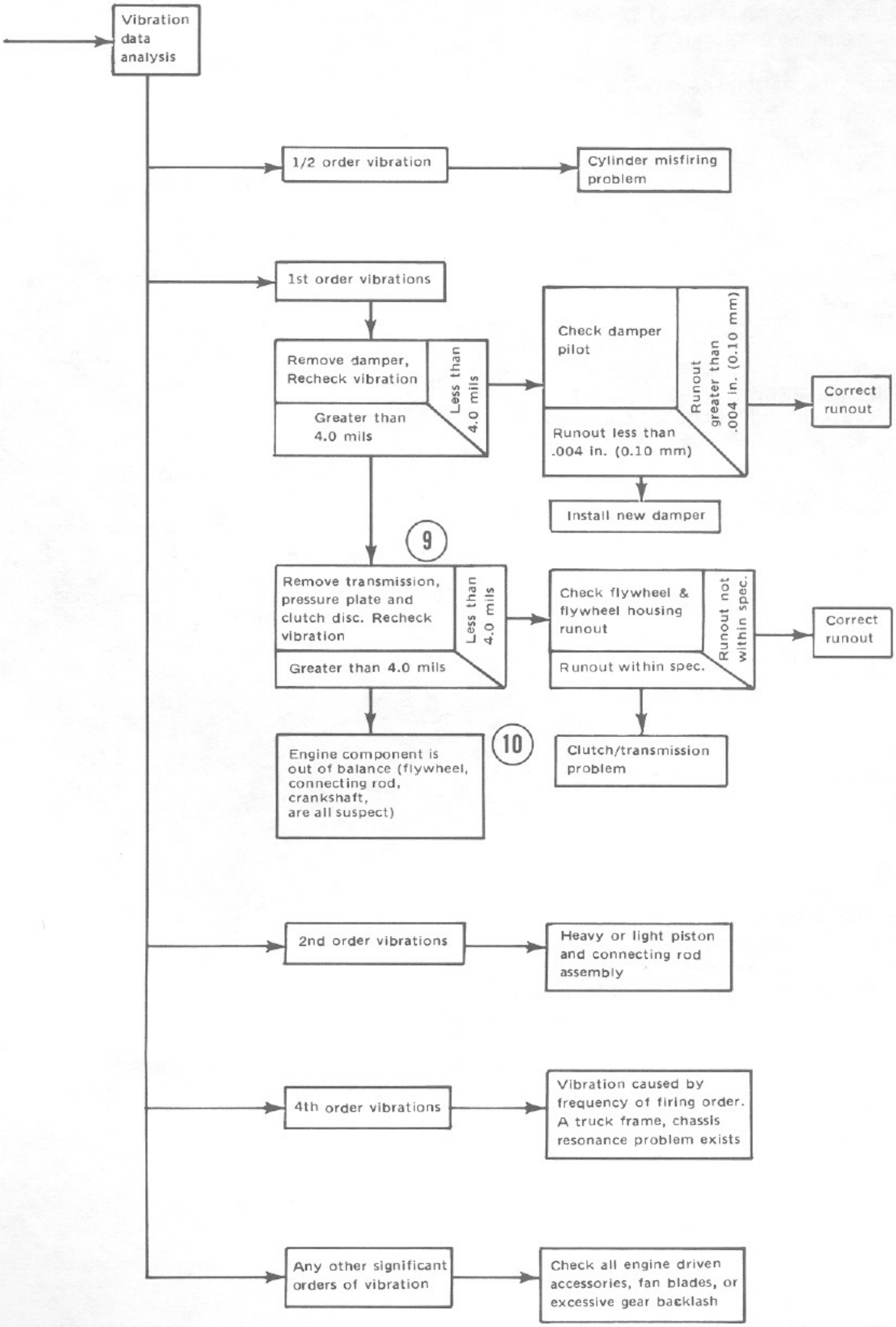
2. Loose Fuel Injection Nozzle Nut(s) . . . A loose fuel injection nozzle nut or a bad O-ring seal on the nozzle inlet can cause fuel leakage. Tighten nozzle nut(s) to 42 ± 7 N•m (31 ± 5 lb ft) and check for a bad O-ring seal.

3. Bad Fuel Nozzle(s) . . . Check fuel nozzle(s) for cracks in inlet fitting, inlet line, or nozzle body. If you do not see a crack, start the engine and visually inspect each nozzle for leaks. Cracks in the inlet fitting and nozzle body are nozzle defects. Cracks in the inlet line are caused by the nozzle not being tightened correctly. Check for leakage at the fuel nozzle cap. If no leakage is seen the fuel nozzles can be removed and checked.

ENGINE VIBRATION TROUBLESHOOTING


COMPLAINT: Excessive Vibration
1
Question customer to determine nature of complaint
2
Start engine, run through entire idle speed range and check for loose mountings on all vibrating components
All brackets, mounts and bolts are tight
Loose, broken mounts
Repair or tighten all fixtures and retest
Still has vibration
No vibration
No further test necessary
3
Run engine through entire idle speed range with clutch disengaged.
No change in vibrations
Vibrations stop
Problem with clutch disc unbalance or alignment. Repair or replace clutch disc
4
Use vibration instrument on cab components
5
Measure vibration of cab components identified in Step 2. Identify the frequency of the objectionable vibration
All other frequency orders need further analysis
1/2 order vibrations
4th order vibrations
6
Use vibration instrument on engine
7
Measure vibration of engine through entire speed range. Record speeds and amplitudes w/filter out
Some amplitudes measured are over 4.0 mils
All amplitudes less than 4.0 mils
Engine within Caterpillar Specs
Run the engine at RPM where overall amplitudes were over 4.0 mils with filter in. Measure 1st order amplitudes
1st order amplitudes greater than 4.0 mils
8
Run engine at high idle. Make vibration measurements with filter in. Record any frequencies with amplitudes over 4.0 mils
Check all vibrations over 4.0 mils for each order of frequency
1st order amplitudes less than 4.0 mils
Engine within Caterpillar Specs

ENGINE VIBRATION TROUBLESHOOTING (Con't)


Vibration data analysis
1/2 order vibration
Cylinder misfiring problem
1st order vibrations
Remove damper, Recheck vibration
Less than 4.0 mils
Greater than 4.0 mils
Check damper pilot
Runout greater than .004 in. (0.10 mm)
Runout less than .004 in. (0.10 mm)
Correct runout
Install new damper
9
Remove transmission, pressure plate and clutch disc. Recheck vibration
Less than 4.0 mils
Greater than 4.0 mils
Check flywheel & flywheel housing runout
Runout not within spec.
Runout within spec.
Correct runout
Clutch/transmission problem
10
Engine component is out of balance (flywheel, connecting rod, crankshaft, are all suspect)
2nd order vibrations
Heavy or light piston and connecting rod assembly
4th order vibrations
Vibration caused by frequency of firing order. A truck frame, chassis resonance problem exists
Any other significant orders of vibration
Check all engine driven accessories, fan blades, or excessive gear backlash

Engine Vibration Troubleshooting

1. The customer must be asked questions to determine whether his complaint is valid, or whether his diagnosis of the actual problem is correct.

Some of the questions that must be asked are as follows:

a. What components are vibrating?

b. In what speed range does this vibration become excessive?

c. Does clutch operation affect the vibration?

d. What is the history of the problem?

2. Run the engine through the idle speed range and note all vibrating components. Look for any loose or broken mounts, brackets and fasteners. Repair and tighten any fixtures.

3. Check idle speed range with clutch disengaged. If vibrations subside, there is a balance problem with the clutch disc. The clutch disc must be repaired or replaced.

4. Further analysis requires the use of a vibration instrument. Any instrument which can accurately measure the displacement of the vibration (usually in mils-inch/1000) and the frequency (cycles per minute) will be sufficient.

NOTE: A vibration instrument such as the IRD Mechanalysis Model 320 or an equivalent instrument can be used to analyze vibration.

5. Measure vibration of cab components which have the objectionable vibration.

Run engine slowly through the speed range and measure vibration with the instrument filter OUT. When peak amplitudes are found, run the engine at the speeds they occur and with the instrument filter IN, find the frequency of the vibration.

If the frequency of vibration is ½ times of engine rpm (½ order), the vibration is caused by a cylinder misfiring. This must be corrected before further vibration analysis is made.

If the frequency of vibration is 4 times engine rpm, no corrective action can be taken on the engine because this is the firing frequency of the 3208 Engine. The problem is in the cab or chassis resonance.

If frequency is some order other than ½ or 4th, then further measurements must be made on the engine.

6. Measurements taken on the engine must be made perpendicular to the crankshaft at the front and rear of the engine in vertical and horizontal directions.

7. Record all vibrations over 4.0 mils and the engine rpm at which it occurs (100 rpm intervals are sufficient) with instrument filter OUT. Note any sudden increase and decrease in amplitudes. These occur in resonant speed ranges.

If no amplitudes exceed 4.0 mils, the engine is within Caterpillar Specs.

If amplitudes exceed 4.0 mils, the vibrations must be measured with the instrument filter IN to obtain the frequency of the vibrations.

8. Run the engine at high idle. With the instrument filter IN, check the frequency range and record any amplitudes over 4.0 mils and the corresponding frequency. Analysis of vibrations for the possible causes is done by identifying the frequency of the vibration and where on the engine it is the greatest magnitude.

9. Before vibration is rechecked, rotate the crankshaft to No. 1 cylinder top center position. Install a ⅜-16 bolt 1¾" long with a nut into the flywheel at the 9 o'clock position.

10. The location on the engine at maximum vibration (front or rear) can help pinpoint the cause of the vibration. High rear vibrations could be caused by the flywheel.

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General Instructions (D & A)

The following instructions will prove helpful to disassemble and assembly engine components. The information should be read and then referred to as necessary.

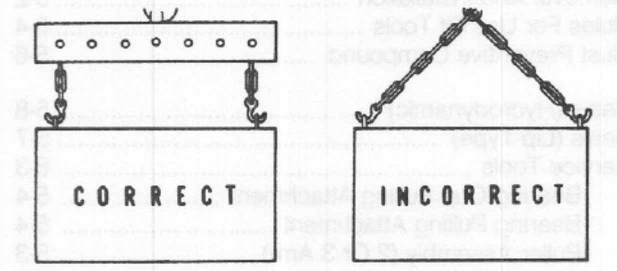
Cleanliness

Whenever hydraulic, fuel, lubricating oil or air lines are disconnected, clean the point of disconnection and the adjacent area. As soon as the disconnection is made, cap, plug or tape the line or opening to prevent entry of foreign material. The same recommendations for cleaning and covering apply when access covers or inspection plates are removed.

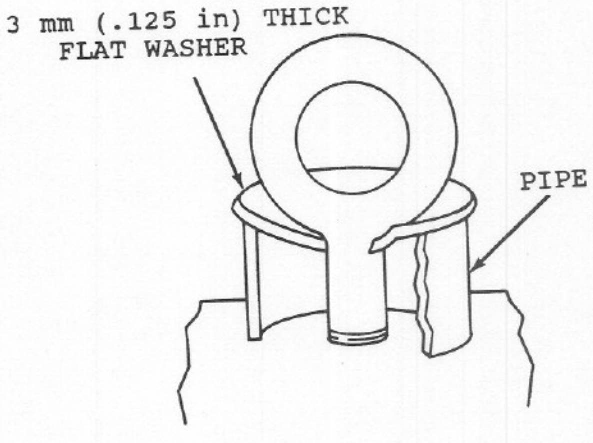
Clean and inspect all parts. Be sure all passages and holes are open. Cover all parts to keep them clean. Be sure parts are clean when installed. Leave new parts in their containers until ready for assembly.

Removal And Installation

Unless otherwise specified, all removals should be accomplished using an adjustable lifting beam. All supporting Members (chains and cables) should be parallel to each other and as near perpendicular as possible to the top of the object being lifted.



When it is necessary to remove a component on an angle, remember that the capacity of an eyebolt diminishes as the angle between the supporting members and the object becomes less than 90°. Eyebolts and brackets should never be bent and should only have stress in tension. A length of pipe and a washer can be used, as shown, to help relieve these stresses on eyebolts.



Forged eyebolts are available. Each eyebolt has a maximum load recommendation.

EYEBOLT LOAD RECOMMENDATION

SIZE	PART NO.	MAXIMUM LOAD lbs.	MAXIMUM LOAD kg
¼"—20	1P7403	600	272.3
5/16"—18	1P7404	1125	510.6
⅜"—16	1P7405	1625	737.6
7/16"—14	1P7406	2250	1021.3
½"—13	1P7407	3000	1361.7
⅝"—11	2D1201	5000	2269.5
¾"—10	1P7409	6250	2836.9

Some removals require the use of lifting fixtures to obtain proper balance and to provide safe handling.

If a part resists removal, check to be certain all nuts and bolts have been removed and that an adjacent part is not interfering.

Disassembly And Assembly

When assembling an engine, complete each step in turn. Do not partially assemble one part and start assembling some other part. Make all adjustments as recommended. Always check the job after it is completed to see that nothing has been overlooked.

Lubrication For A Rebuilt Engine

It is very important for a rebuilt engine to have "adequate" (needed) lubrication during the first seconds of operation. A "dry start" (without needed lubrication) on a rebuilt engine or an engine that has been in storage can cause bearing damage.

To prevent the possibility of a "dry start" and bearing damage during the first few seconds of running, use the 1P0540 Flow Checking Tool Group and shop air pressure to pressure lubricate (fill the main oil passage with oil under pressure) all rebuilt engines and all engines that have been in storage.

Procedure For Pressure Lubrication

1. Clean the tank of the 1P0540 Flow Checking Tool Group thoroughly, and set the pressure regulator to 240 ± 35 kPa (35 ± 5 psi).

⚠ WARNING

Air pressure should not be more than 345 kPa (50 psi) at any time.

2. Put the correct engine oil into the tank. Use a minimum of 30% of the engine oil capacity. For some engines it will be necessary to fill the tank several times to get the correct amount of oil in the engine.
3. Connect the tooling to the main oil passage of the engine.
4. Add air pressure to the tank, with the regulator set at 240 ± 35 kPa (35 ± 5 psi). Although the tank has a hand pump, it is difficult to get enough air pressure to do the job with the hand pump. Therefore , use of shop air is recommended.
5. Let the engine oil flow into the oil passage under pressure.

Fill the crankcase with the correct engine oil. The amount of oil used in the pressure lubrication procedure must be subtracted from the recommended refill capacity in the Operation Maintenance Manual. If the engine is not going to be used for a long time, do the above procedure again before the first start.

If shop air is not available, for charging the tank, the hand pump may be used to get the minimum required pressure.

NOTICE

DO NOT use the same 1P0540 Flow Checking Tool Group for both "pressure lubrication application" and for checking fuel flow. Incorrect cleaning is probable if the tool is used for both fuel and lubrication oil. Even a minute amount of dirt in the fuel system can cause fuel nozzle failure.

Initial Operation After Engine Reconditioning

The quality of oil control components used in Caterpillar engines is such that, following engine reconditioning (with Caterpillar Service Parts), only an initial operational check is necessary before continued operation in normal service.

The purpose of this initial operational check is to: insure that the engine has been assembled properly; determine if proper pressures and temperatures are maintained in the lubrication, cooling, and fuel systems; correct any leaks; perform necessary adjustments (such as valve clearance, governor high and low idle speeds, etc.); check the set point.

To provide a safe, uniform initial operational check, the following procedure is recommended:

1. Motor engine at cranking speed until oil pressure is observed.
2. Operate engine for 10 minutes at low idle.
3. Operate engine for 15 minutes at half-load and 3/4 rated engine speed.
4. Operate engine for 30 minutes at rated load and speed.

Service Tools

Puller Assembly (2 Or 3 Arm)

Two or three arm pullers assemblies can be used to remove gears, bearing cages, hubs, bearings, shafts, etc.

Push Pullers

Push Pullers can be used to remove pulleys, gears, shafts, etc., and can be used in a variety of pulling combinations.

Bearing Pulling Attachment

Bearing Pulling Attachments can be used with forcing bolts, to remove shafts, bearings, gears, etc. They can be used with Push Pullers to provide a variety of pulling combinations.

Bearing Cup Pulling Attachment

Bearing Cup Pulling Attachments are used to remove bearing races or cups, sleeve-type bearings, bearings, seats, etc. and can be used with Push Pullers.

Rules For Use Of Tools

Rule 1: Always use safe Tools.

Rule 2: Keep tools in safe working condition.

Rule 3: Use the correct tool for the job.

Rule 4: Common sense with tools pays off.

Pressing Parts

When pressing one part into another, use 5P3931 Anti-Seize Compound or a molybdenum disulfide base compound to lubricate the mating surfaces.

Assemble tapered parts dry. Before assembling parts with tapered splines, be sure the splines are clean, dry and free from burrs. Position the parts together by hand to mesh the splines before applying pressure.

If parts which are fitted together with tapered splines are not tight, inspect the tapered splines and discard if worn.

Bolts And Bolt Torque

A bolt which is too long may "bottom" before the head is tight against the part it is to hold. The threads can be damaged when a "long" bolt is removed.

If a bolt is too short, there may not be enough threads engaged to hold the part securely.

Apply proper torque values to all bolts and nuts when assembling Caterpillar Equipment. When a specific torque value is required, the value is listed in the Specifications Section of this Service Manual. Tighten all other bolts and nuts for general usage, hydraulic valve bodies, or taperlock studs to the torque values given in the torque charts shown in this Service Manual.

NOTE: Take care to avoid mixing metric and inch fasteners. Mismatched or incorrect fasteners can result in mechanical damage or malfunction, or possible personal injury. Original fasteners removed during disassembly should be saved for assembly when possible. If new ones are required, caution must be taken to replace with one that is of same part number and grade.

Metric thread fasteners are identified by material strength (grade) numbers on bolt heads and nuts. Numbers on bolts will be 8.8, 10.9, etc. Numbers on nuts will be 8, 10, etc.

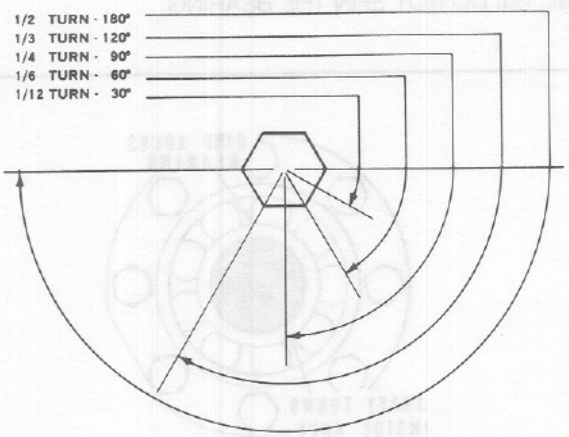
T-T-T Procedure

A torque-turn-tighten (T-T-T) procedure is used in many specifications and instructions.

1. Clean the bolt and nut threads.
2. Put lubrication of the threads and the seat face of the bolt and nut.
3. Turn the bolt or the nut tight according to the torque specification.
4. Put a location mark on the part and on the bolt head or nut.
5. Turn the bolt or the nut tighter the amount of degrees according to the specifications

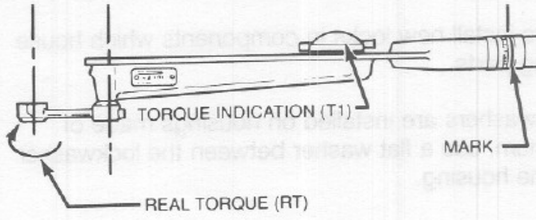
1	360°
1/2	180°
1/3	120°
1/4	90°
1/6	60°
1/12	30°

NOTE: The side of a nut or bolt head can be used for reference if a mark can not be put on.



Torque Wrench Extension

When a torque wrench extension is used with a torque wrench, the torque indication on the torque wrench will be less than the real torque.



(E) Torque wrench drive axis-to-torque wrench extension drive axis. (W) Mark on handle-to-torque wrench drive axis.

1. Put a mark on the handle. Measure the handle from the mark to the axis of the torque wrench drive (W).
2. Measure the torque wrench extension from the torque wrench drive to the axis of the torque wrench extension drive (E).
3. To get correct torque indication (TI) when the real torque (RT) is known:

$$TI = \frac{RT \times W}{W + E}$$

Example: W = 304.8 mm (12 in); E = 65.0 mm (2.56 in); RT (from specifications) = 17 N•m (125 lb ft).

$$TI = \frac{(170 \times 304.8)}{(304.8 + 65.0)} \text{ or } (140 \text{ N}\cdot\text{m})$$

$$TI = \frac{125 \times 12}{12 + 2.56} \text{ or } 103 \text{ lb ft}$$

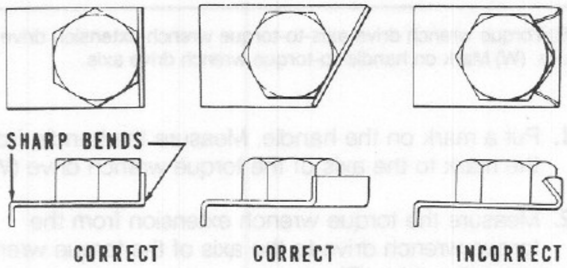
4. Hold the torque wrench handle with the longest finger of the hand over the mark on the handle to get the real torque (RT) with low torque indication (TI) on the torque wrench.

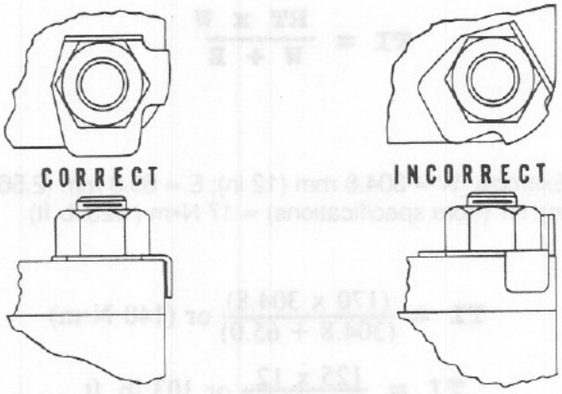
Locks

Flat metal locks must be installed properly to be effective. Bend one end of the lock around the edge of the part. Bend the other end against one flat surface of the nut of bolt head.

Always install new locks in components which house moving parts.

If lockwashers are installed on housings made of aluminum, use a flat washer between the lockwasher and the housing.





Lines And Wires

When removing or disconnecting a group of lines or wires, tag each one to assure proper assembly.

Lubrication

Where applicable, fill the compartments of the components serviced with the amount, type and grade of lubricant recommended in the Operation Maintenance Manual.

Rust Preventive Compound

Clean the rust preventive compound from all machined surfaces of new parts before installing the part.

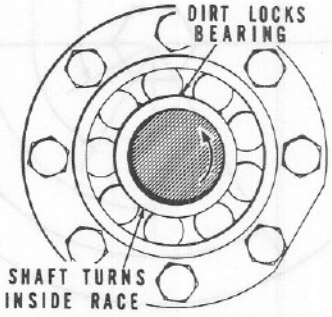
Shims

When shims are removed, tie them together and identify them as to location. Keep shims clean and flat until they are reinstalled.

Bearings

Anti-Friction Bearings

When an anti-friction bearing is removed, cover it to keep out dirt and abrasives. Wash the bearings in nonflammable cleaning solution and allow them to drain dry. The bearings may be dried with compressed air, but DO NOT SPIN THE BEARING.



Discard the bearings if the races and balls or rollers are pitted, scored or burned. If the bearing is serviceable, coat it with oil and wrap it in clean paper. DO NOT unwrap new bearings until time of installation.

The life of an anti-friction bearing will be shortened if not properly lubricated.

Double Row, Tapered Roller

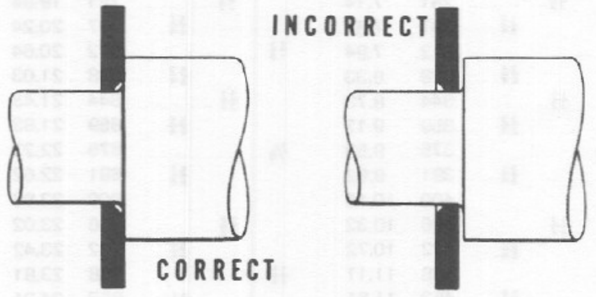
Double row, tapered roller bearings are precision fit during manufacture and the components are not interchangeable. The cups, cones and spacers are usually etched with the same serial number and letter designator. If no letter designators are found, wire the components together to assure correct installation. Reusable bearing components should be installed in their original positions.

Heating Bearings

Bearings which require expansion for installation should be heated in oil not to exceed 121° C (250° F). When more than one part is heated to aid in assembly, they must be allowed to cool and then pressed together again. Parts often separate as they cool and shrink.

Installation

Lubricate new or used bearings before installation. Bearings that are to be preloaded must have a film of oil over the entire assembly to obtain accurate preloading. When installing a bearing, spacer or washer against a shoulder on a shaft, be sure the chamfered side is toward the shoulder.



When pressing bearings into a retainer or bore, apply pressure to the outer race. If the bearing is pressed on the shaft, apply pressure on the inner race.

Preload

Preload is an initial force placed on the bearing at the time of assembly.

Determine preload or end clearance form the Specifications Section of this Service Manual. Care should be exercised in applying preload. Misapplication of preload to bearings requiring end clearance can result in bearing failure.

Sleeve Bearings

DO NOT INSTALL SLEEVE BEARINGS WITH A HAMMER. Use a press, if possible and apply the pressure directly in line with the bore. If it is necessary to drive on a bearing, use a driver or a bar with a smooth flat end. If a sleeve bearing has an oil hole, align it with the oil hole in the mating part.

Gaskets

Be sure the holes in the gaskets correspond with the lubricant passages in the mating parts. If it is necessary to make gaskets, select stock of the proper type and thickness. Be sure to cut holes properly. Blank gaskets can cause serious damage.

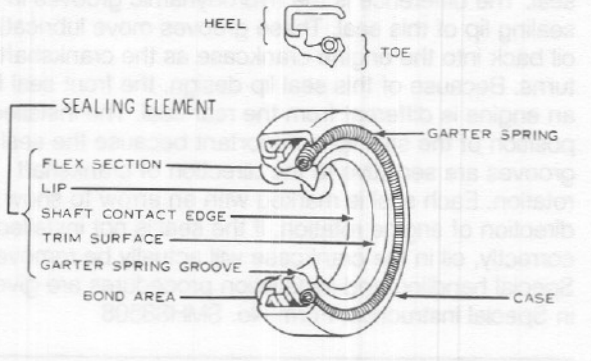
Batteries

Clean batteries by scrubbing with a solution of baking soda and water. Rinse with clear water. After cleaning, dry thoroughly and coat terminals and connections with anti-corrosion compound or grease.

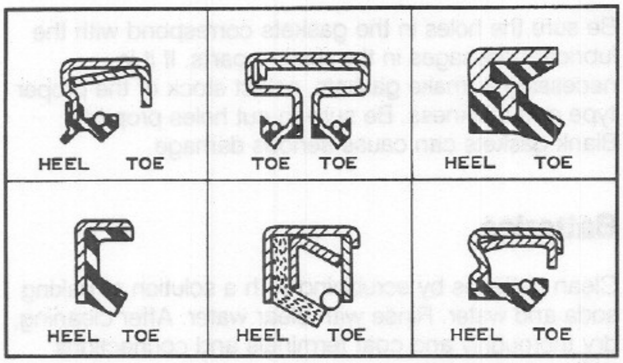
If an engine is not to be used for a long period of time, remove the batteries. Store them in a cool, dry place. A small charge should be introduced periodically to keep the specific gravity rating at the recommended level.

Seals (Lip-Type)

Generally the toe or spring-loaded lip of an oil seal faces the oil being sealed or the oil having the higher pressure. The toe or lip of a grease seal faces away from the lubricant being sealed. Unless otherwise specified, use the preceding rules for installing lip-type seals.



The main parts of a lip-type seal are the case, sealing element, and the garter spring. The illustration shows the construction of a simple lip-type seal. The cross section shows the terms "heel" and "toe" used to identify the sides of various types of seals.

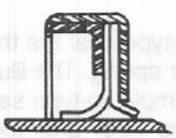


Lubricate the lips of lip-type seals before installation. Use the same type of lubricant which the seal will be operating. Do Not use grease on any seal except a grease seal.

If during installation, the seal lip must pass over a shaft that has splines, a keyway, rough surface or a sharp edge, the lip can easily be damaged. Shim stock or other such material can be formed around the area to provide a smooth surface over which to slide the seal.

Seals (Hydrodynamic)

The hydrodynamic seal is different from the lip-type seal. The difference is the hydrodynamic grooves in the sealing lip of this seal. These grooves move lubrication oil back into the engine crankcase as the crankshaft turns. Because of this seal lip design, the front seal for an engine is different from the rear seal. The installed position of the seal lip is important because the seal grooves are sensitive to the direction of crankshaft rotation. Each seal is marked with an arrow to show the direction of engine rotation. If the seal is not installed correctly, oil in the crankcase will actually be removed. Special handling and installation procedures are given in Special Instruction, Form No. SMHS8508



Conversion Chart (Inches To MM)

inches		mm	inches		mm
1/64	.016	0.40	33/64	.516	13.10
1/32	.031	0.79	17/32	.531	13.49
3/64	.047	1.19	35/64	.547	13.89
1/16	.062	1.59	9/16	.562	14.29
5/64	.078	1.98	37/64	.578	14.68
3/32	.094	2.38	19/32	.594	15.08
	.100	2.54		.600	15.24
7/64	.109	2.78	39/64	.609	15.48
1/8	.125	3.18	5/8	.625	15.88
9/64	.141	3.57	41/64	.641	16.27
5/32	.156	3.97	21/32	.656	16.67
11/64	.172	4.37	43/64	.672	17.07
3/16	.188	4.76	11/16	.688	17.46
13/64	.203	5.16	45/64	.703	17.86
7/32	.219	5.56	23/32	.719	18.26
15/64	.234	5.95	47/64	.734	18.65
1/4	.250	6.35	3/4	.750	19.05
17/64	.266	6.75	49/64	.766	19.45
9/32	.281	7.14	25/32	.781	19.84
19/64	.297	7.54	51/64	.797	20.24
5/16	.312	7.94	13/16	.812	20.64
21/64	.328	8.33	53/64	.828	21.03
11/32	.344	8.73	27/32	.844	21.43
23/64	.359	9.13	55/64	.859	21.83
3/8	.375	9.53	7/8	.875	22.23
25/64	.391	9.92	57/64	.891	22.62
	.400	10.16		.900	22.86
13/32	.406	10.32	29/32	.906	23.02
27/64	.422	10.72	59/64	.922	23.42
7/16	.438	11.11	15/16	.938	23.81
29/64	.453	11.51	61/64	.953	24.21
15/32	.469	11.91	31/32	.969	24.61
31/64	.484	12.30	63/64	.984	25.00
1/2	.500	12.70	1	1.000	25.40

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⚠ WARNING

DISCONNECT BATTERIES BEFORE PERFORMANCE OF ANY SERVICE WORK.

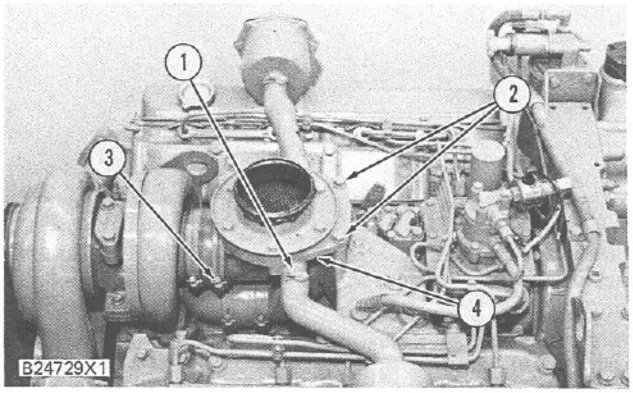
AIR INLET MANIFOLD

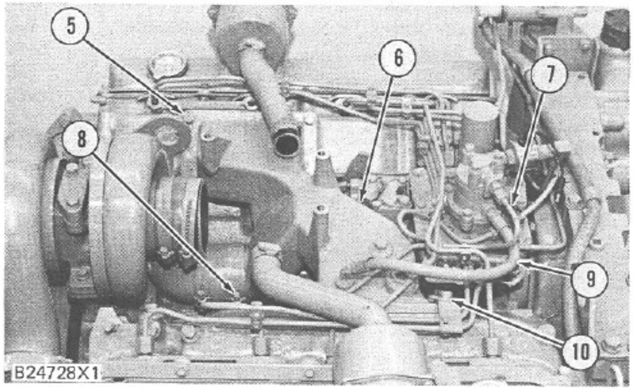
REMOVE AIR INLET MANIFOLD 1058-11

1. Loosen clamps (1) and (3). Disconnect the hoses.
2. Remove bolts (2) and elbow (4).
3. Loosen clamps (8) and then slide the hose on to the turbocharger.
4. Disconnect hose (9) from the manifold.
5. Remove fuel line (7) from the fuel ratio control.
6. Remove bolts (5). Loosen bolt (10).

NOTE: NOTE: Manifold (6) has an opening (slot) in it for bolt (10).

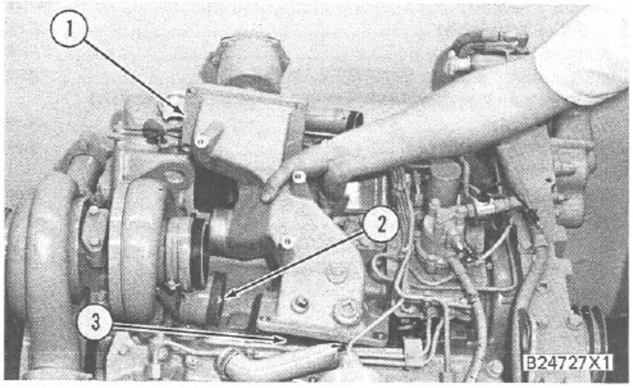
7. Remove manifold (6) and its gaskets.

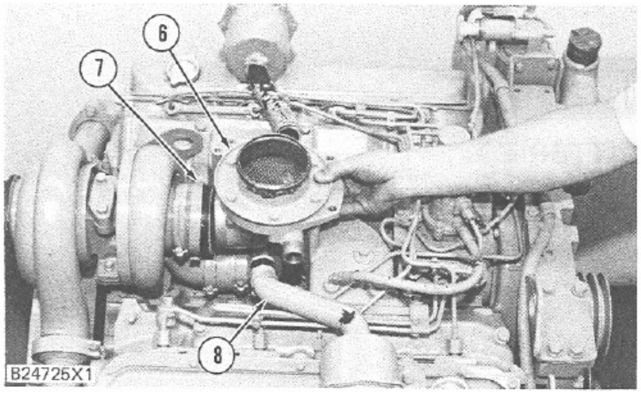


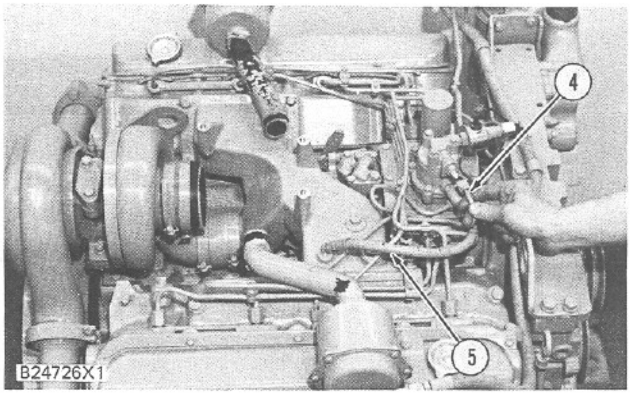


INSTALL AIR INLET MANIFOLD 1058-12

1. Put gaskets (3) and manifold (1) in position and install the bolts that hold it.
2. Put hose (2) in position and tighten the clamps.
3. Install fuel line (4) on the fuel ratio control. Connect hose (5) to the manifold.
4. Put elbow (6) in position on the manifold and install the bolts that hold it.
5. Connect crankcase ventilator hoses (8) to the elbow and tighten the hose clamps.
6. Connect hose (7) to the manifold and tighten the hose clamp.





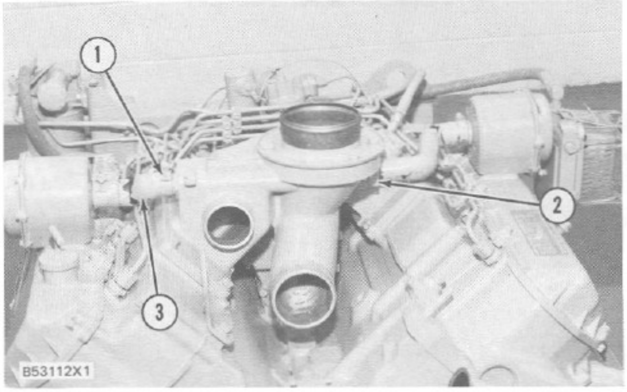


AIR INLET MANIFOLD (LATER)

REMOVE AIR INLET MANIFOLD 1058-11

start by:
a) remove turbocharger

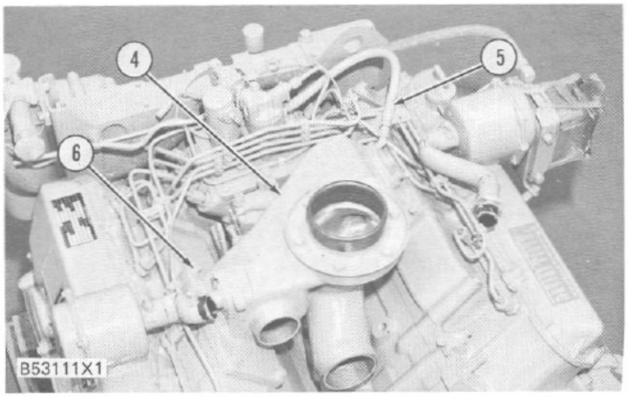
1. Loosen clamps (1) and (2). Disconnect the hoses (3) from the manifold.



2. Remove seven bolts (6). Loosen one bolt (manifold has an opening [slot] in it for this bolt).

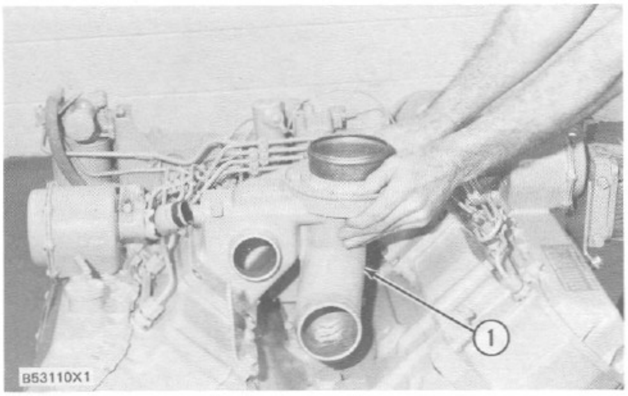
3. Disconnect fuel line (5).

4. Remove air inlet manifold (4) and its gaskets.



INSTALL AIR INLET MANIFOLD 1058-12

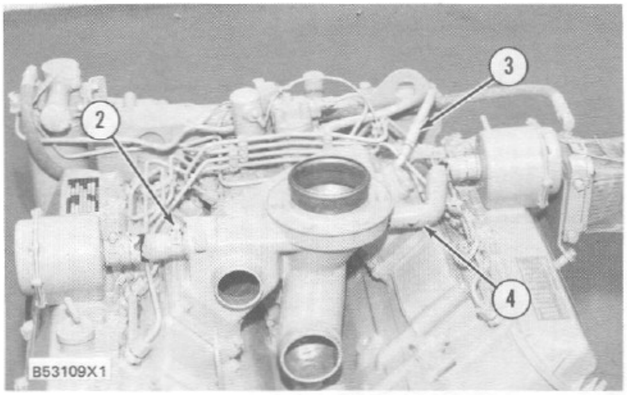
1. Put the air inlet manifold (1) in position on cylinder block and install the seven bolts that hold the manifold in place. Tighten the one bolt (one in manifold slot).



2. Connect the fuel line (3) to the manifold.

3. Connect hoses (4) to the manifold and tighten clamps (2).

end by:
a) install turbocharger



WATER SEPARATOR

REMOVE WATER SEPARATOR 1263-11

NOTICE

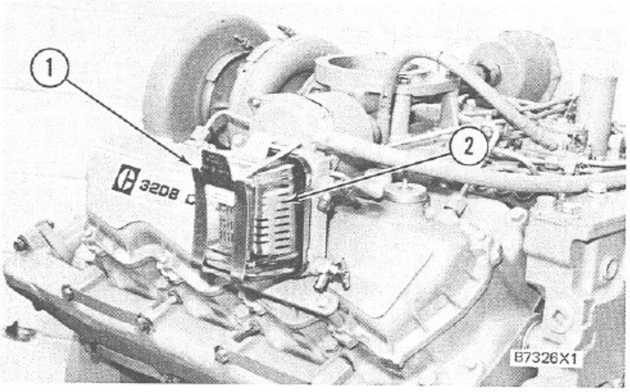
Element (2) is free to fall when clamp (1) is released.

1. Remove clamp (1) and element (2).
2. Disconnect line (4) from the water separator base.
3. Remove the two nuts and water separator base (3).
4. Remove three bolts (6), bracket (5) and spacers.

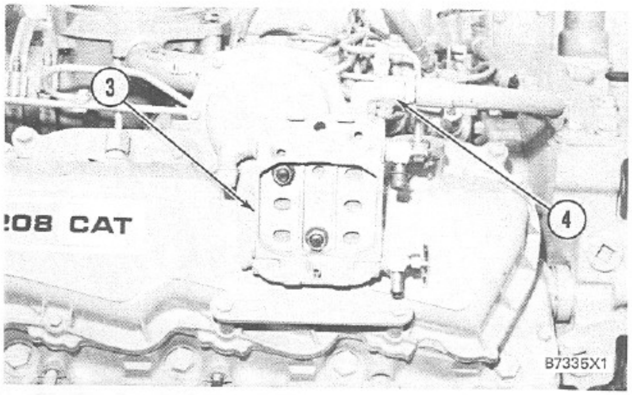
INSTALL WATER SEPARATOR 1263-12

1. Put bracket (1) and three spacers in position. Install the three bolts. Tighten the bolts to a torque of 14 ± 3 N•m (10 ± 2 lb.ft.).
2. Put base (2) in position and install the nuts.
3. Connect line (3) to the base.
4. Put element (4) in position and install clamp (5).

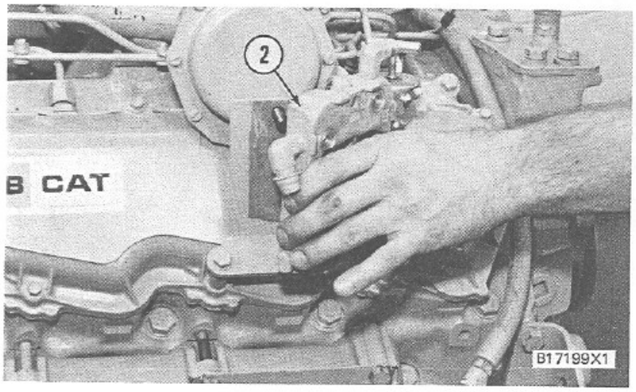
NOTE: Make sure clamp (5) is tight because element (4) is free to fall.



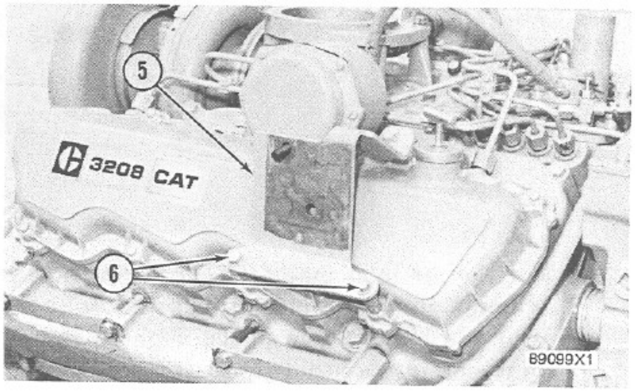
1
2
3208
B7326X1



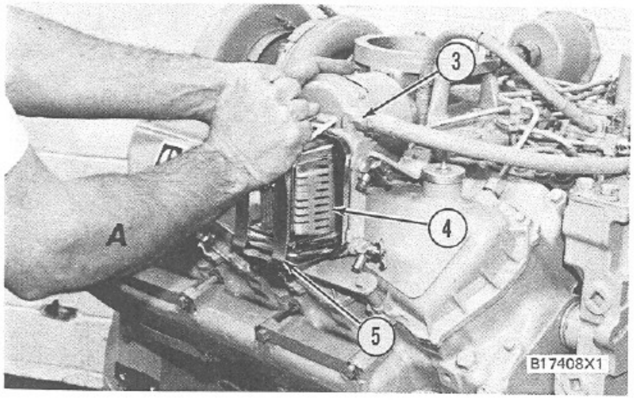
3
4
208 CAT
B7335X1



2
B CAT
B17199X1



5
3208 CAT
6
B9099X1



3
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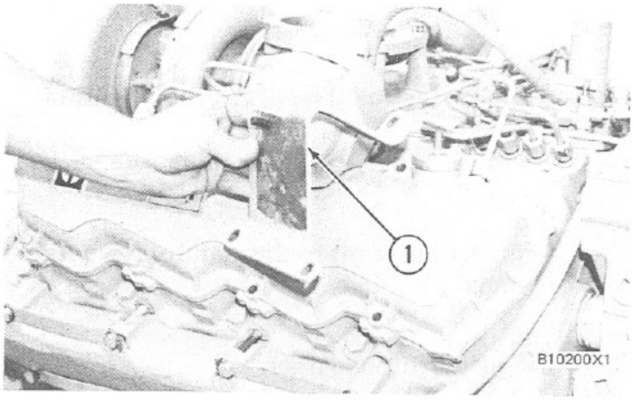
B17408X1

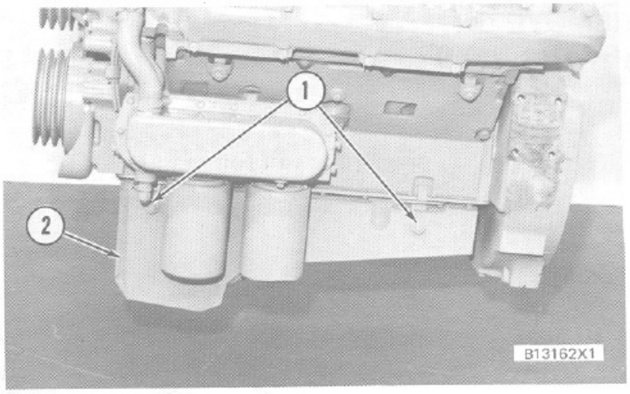


OIL PAN

REMOVE OIL PAN 1302-11

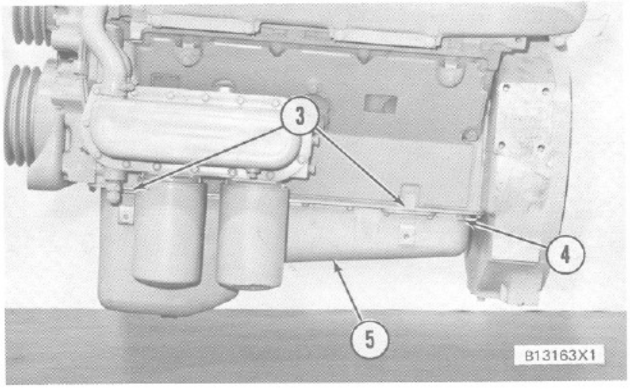
1. Drain the oil from the engine.

2. Remove four bolts (1) and sound suppression (2) from the oil pan.



3. Remove four brackets (3).

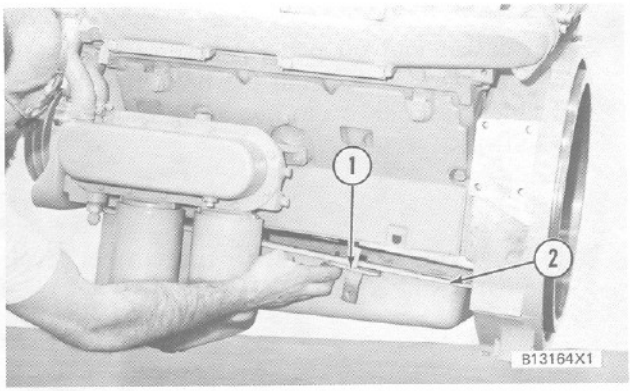
4. Remove bolts (4), oil pan (5) and the gasket.



INSTALL OIL PAN 1302-12

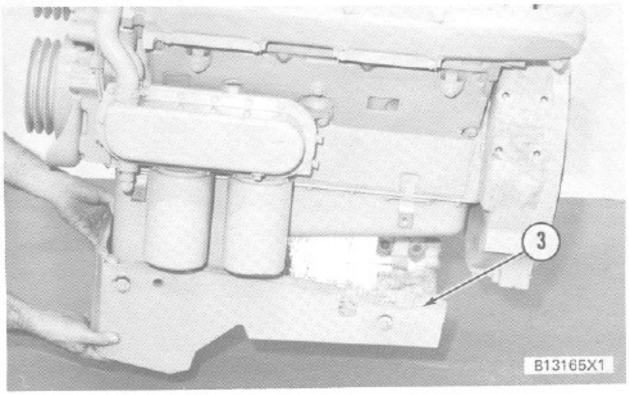
1. Inspect the oil pan gasket. Install a new gasket if needed.

2. Put brackets (1) and oil pan (2) in position.



3. Install the bolts that hold the pan in place. Tighten the bolts to a torque of 23 ± 4 N•m (17 ± 3 lb.ft.).

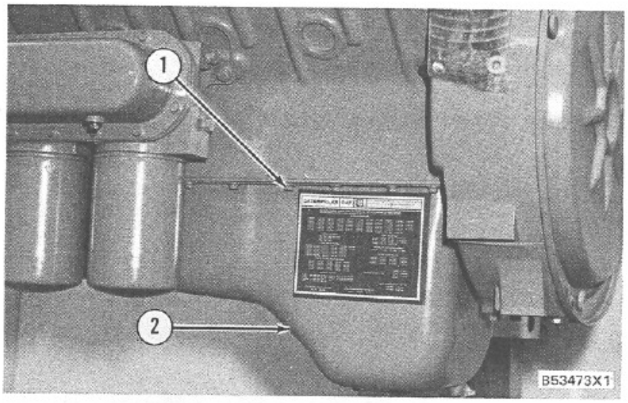
4. Put sound suppression (3) in position and install the bolts that hold it.



5. Fill the engine with oil to the correct level.

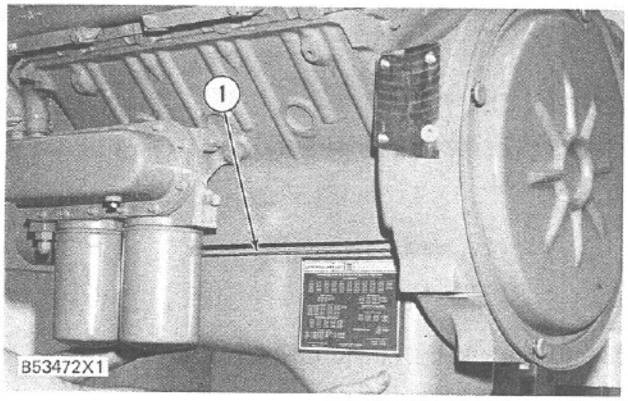
OIL PAN (REAR SUMP)

REMOVE OIL PAN (REAR SUMP) 1302-11



1. Put the engine on a suitable engine stand.
2. Drain the oil from the engine.
3. Remove bolts (1) and then remove oil pan (2) and gasket. Make an inspection of the gasket.

INSTALL OIL PAN (REAR SUMP) 1302-12

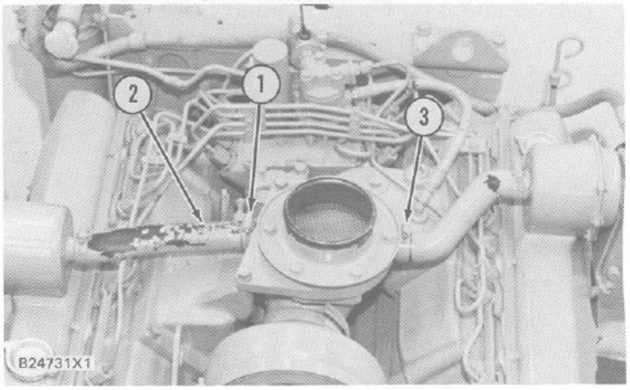


1. Install a new gasket if necessary.
2. Put gasket and oil pan (1) in position on the engine block and install the bolts that hold it. Tighten the bolts to a torque of 23 ± 4 N•m (17 ± 3 lb.ft.).
3. Fill the engine with oil to the correct level. See MAINTENANCE GUIDE.

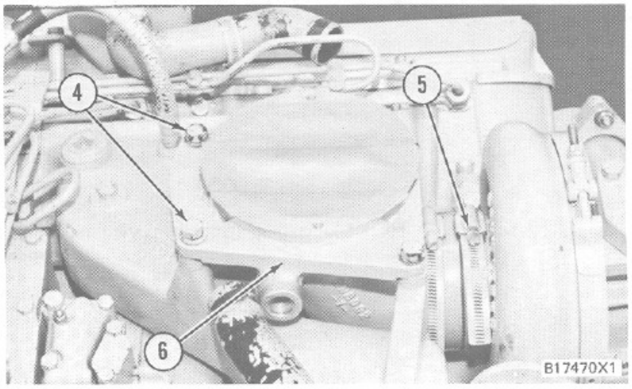
TURBOCHARGER

REMOVE TURBOCHARGER 1052-11

1. Loosen two clamps (1) and (3) and disconnect hoses (2) from the inlet manifold.

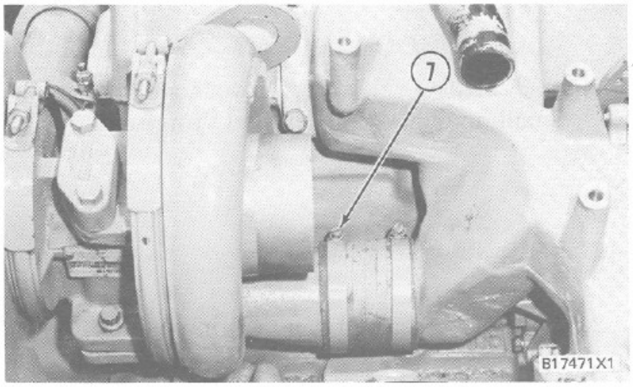

1
2
3
B24731X1

2. Loosen clamp (5).

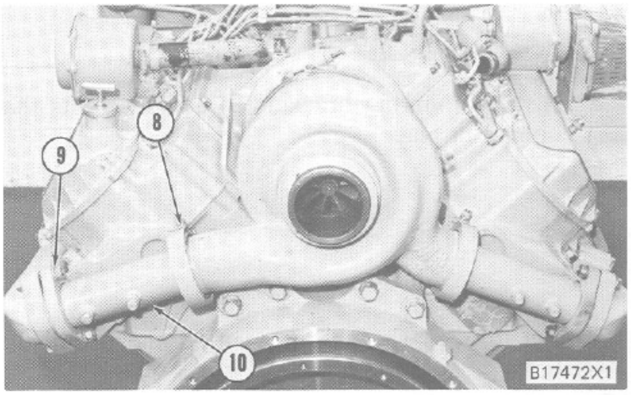

4
5
6
B17470X1

3. Remove three bolts (4) and elbow (6) from the turbocharger.

4. Loosen clamp (7) on the inlet manifold hose.



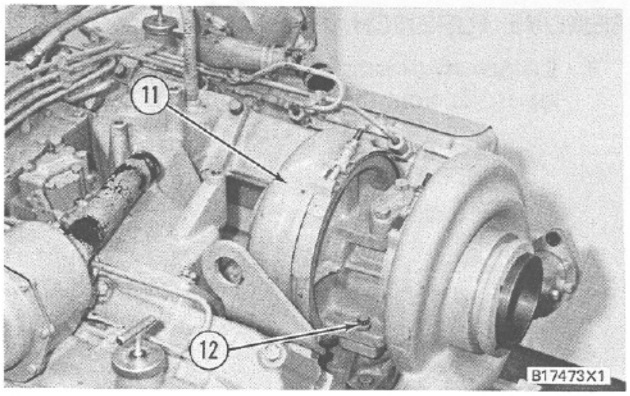
5. Loosen clamp (8) and slide it on to the turbocharger.


8
9
10
B17472X1

6. Loosen bolts and nuts (9) and slide tubes (10) into the exhaust manifold flanges to get clearance for the removal of the turbocharger.

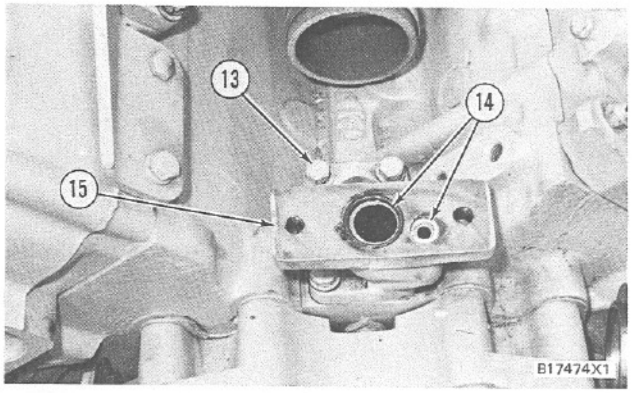
TURBOCHARGER

7. Remove two bolts (12) and turbocharger (11).


11
12
B17473X1

8. Remove two O-ring seals (14).

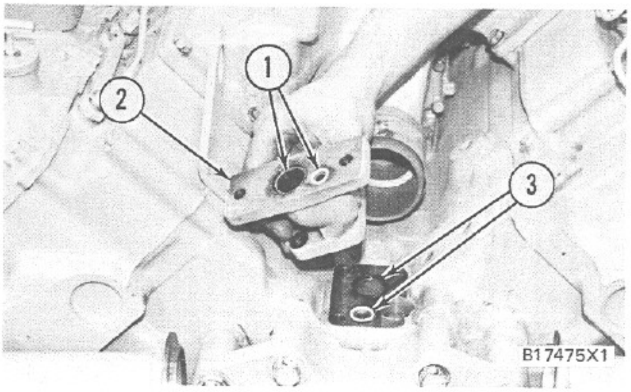
9. Remove three bolts (13) and mounting bracket (15).


13
14
15
B17474X1

10. Remove the two O-ring seals from the cylinder block.

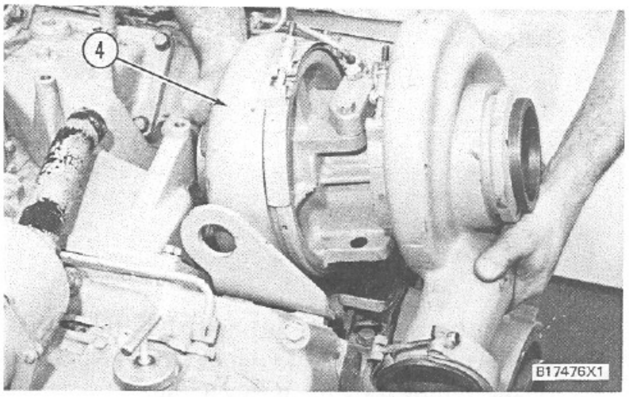
INSTALL TURBOCHARGER 1052-12

1. Inspect all O-ring seals for wear or damage. Put a small amount of oil on the O-ring seals.


1
2
3
B17475X1

2. Put O-ring seals (1) and (3) in position.

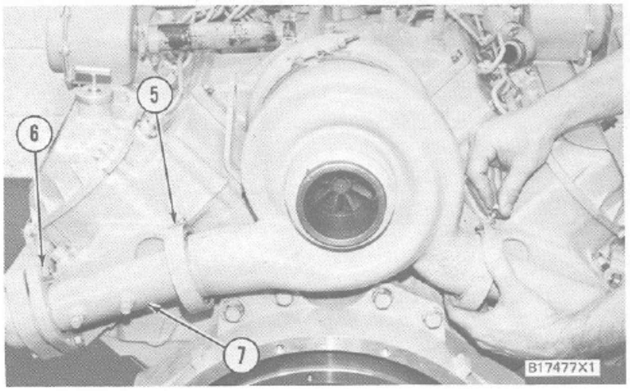
3. Install mounting bracket (2) and the bolts that hold it in place.



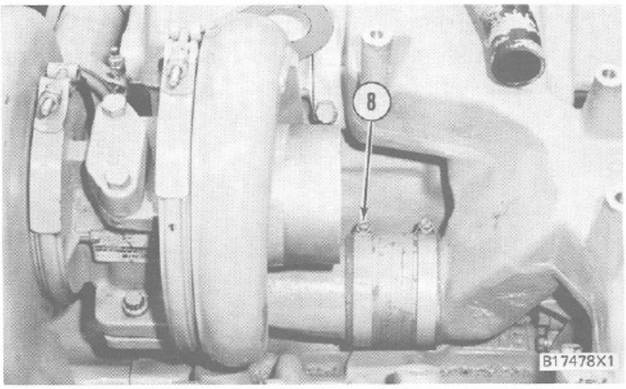
4. Put turbocharger (4) in position and install the bolts.

TURBOCHARGER

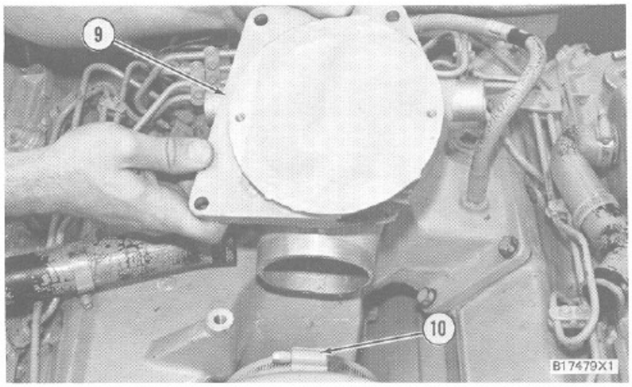
5. Put tube (7) in position and install clamps (5).


5
6
7
B17477X1

6. Put 5P3931 Anti-Seize on the threads of bolts (6). Install bolts (6) and the nuts.

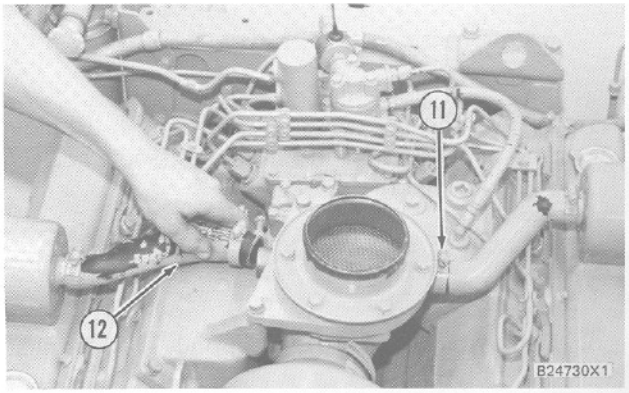


7. Put clamp (8) in position and tighten it.


9
10
B17479X1

8. Put elbow (9) in position and install the bolts.

9. Tighten clamp (10).


11
12
B24730X1

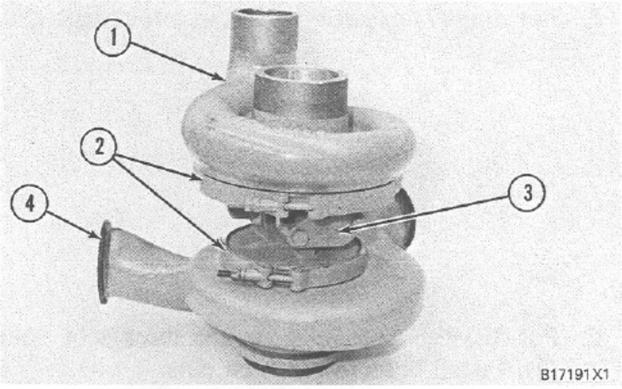
10. Put hoses (12) in position and tighten clamps (11).

TURBOCHARGER (SCHWITZER 4TF555)

DISASSEMBLE TURBOCHARGER (SCHWITZER 4TF555)

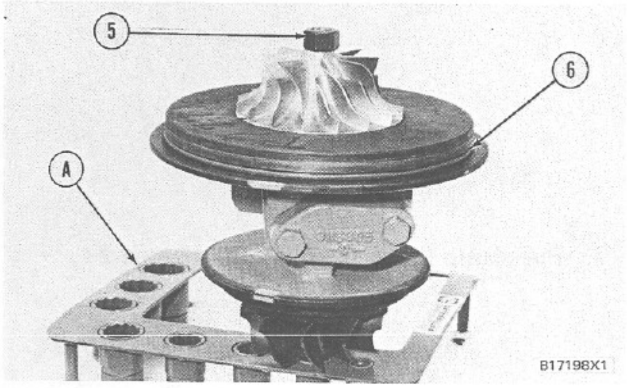
	Tools Needed	A	B	C
9S6343	Fixture Assembly	1		
1P1862	Snap Ring Pliers		1	
1P1863	Snap Ring Pliers			1

start by:
a) remove turbocharger



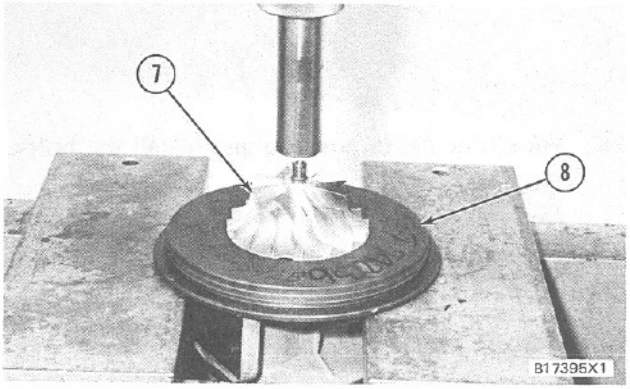
1. Make a mark on compressor housing (1), cartridge assembly (3) and turbine housing for correct installation.

2. Loosen clamp assemblies (2). Remove compressor housing (1) and cartridge assembly (3) from the turbine housing.



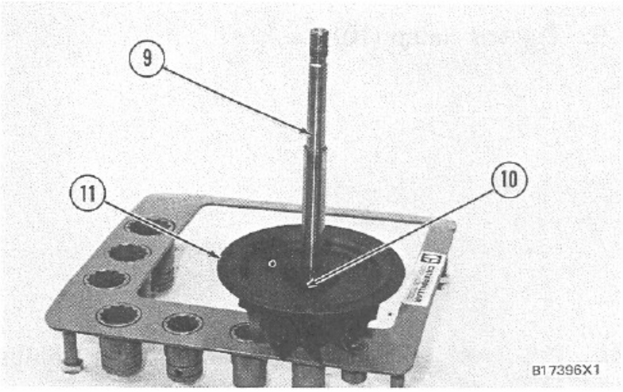
3. Put the cartridge assembly in tooling (A).

NOTICE
When nut (5) is loosened, do not put a side force on the shaft.



4. Remove nut (5) and O-ring seal (6).

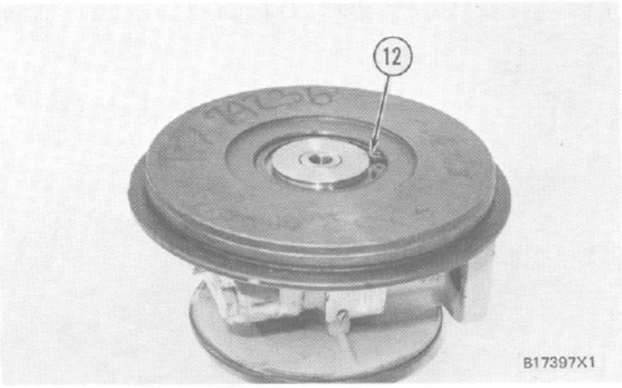
5. Put the cartridge assembly in a press. Remove the shaft assembly from compressor wheel (7) and cartridge (8).



6. Remove seal ring (10) and shroud (11) from shaft assembly (9).

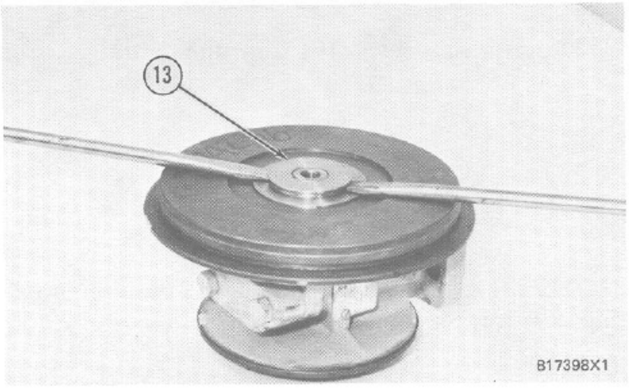
TURBOCHARGER (SCHWITZER 4TF555)

7. Use tooling (B) to remove snap ring (12).

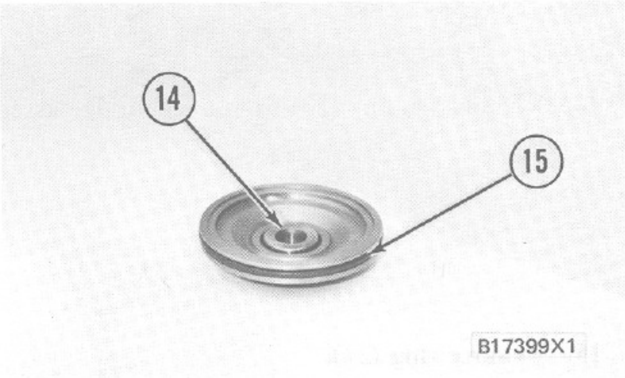

12
B17397X1

NOTICE

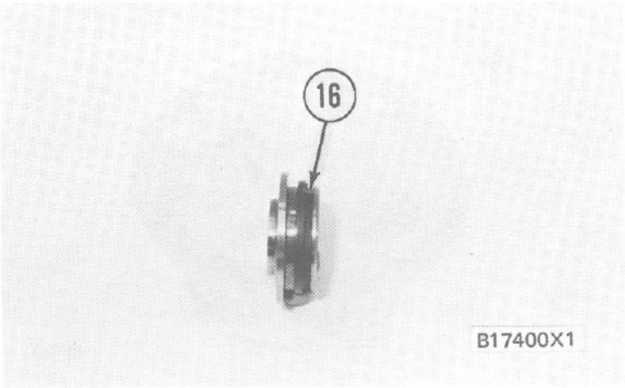
Do not cause damage to insert (13) when it is removed.


13
B17398X1

8. Install screwdrivers as shown. Carefully lift insert (13) out of the cartridge assembly.


14
15
B17399X1

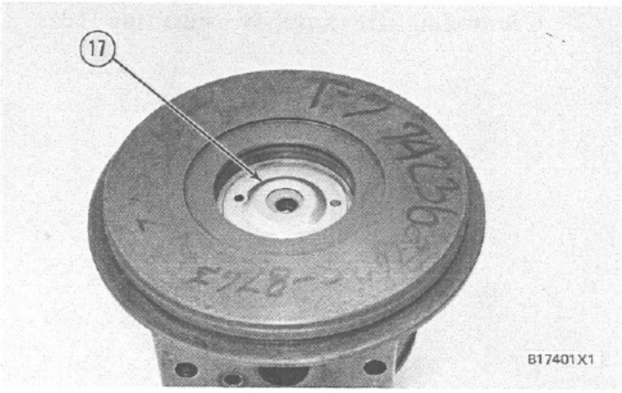
9. Remove sleeve (14) and O-ring seal (15) from the insert.


16
B17400X1

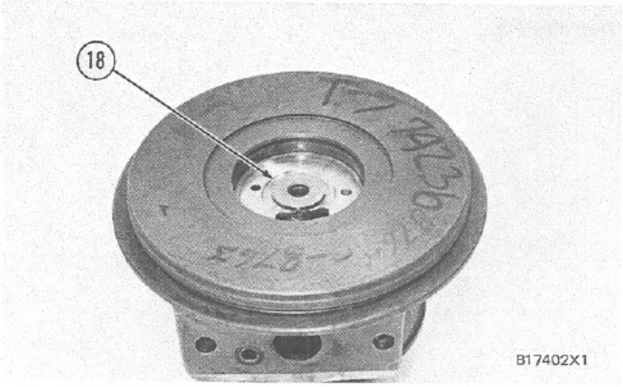
10. Remove two seal rings (16) from the sleeve.

TURBOCHARGER (SCHWITZER 4TF555)

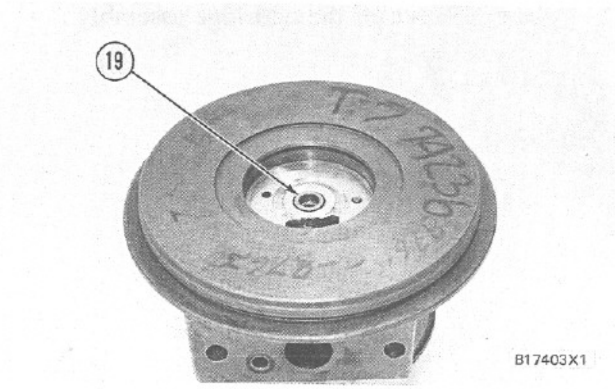
11. Remove deflector (17) from the cartridge assembly.


17
B17401X1

12. Remove ring (18).

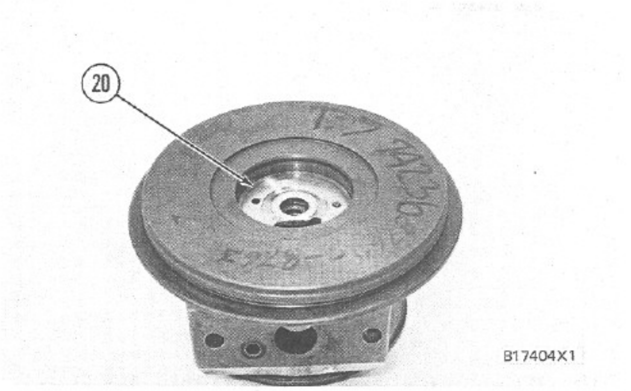

18
B17402X1

13. Remove sleeve (19) from the cartridge assembly.

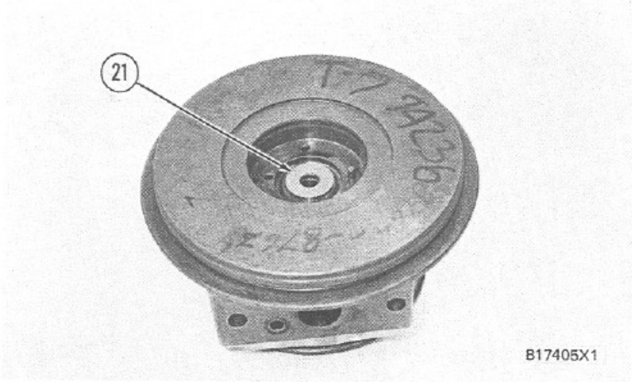

19
B17403X1

NOTE: Make an identification of the position of bearing (20) for assembly purposes.

14. Remove bearing (20) from the cartridge assembly.

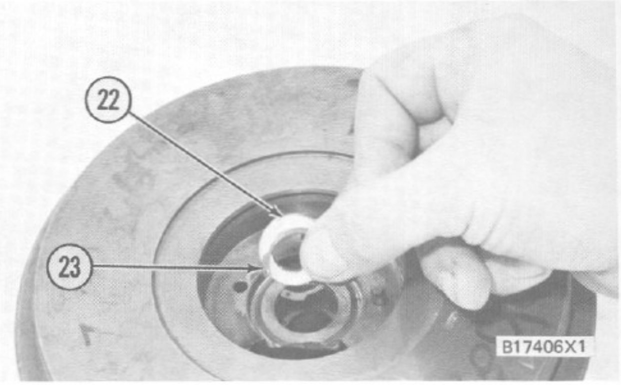

20
B17404X1

15. Remove ring (21).


21
B17405X1

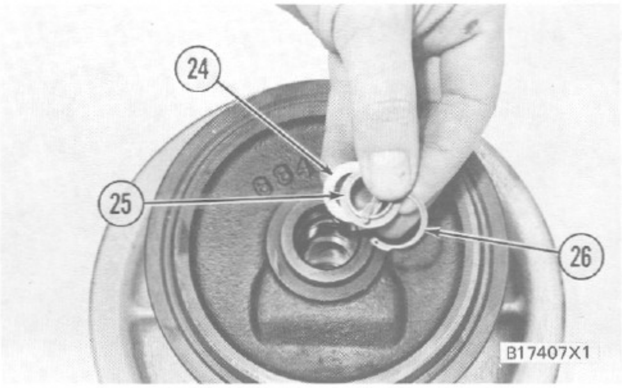
TURBOCHARGER (SCHWITZER 4TF555)

16. Use tooling (C) to remove snap ring (23). Remove sleeve (22) and the lower snap ring.



17. Turn the cartridge housing over. Remove snap ring (26) with tooling (C).

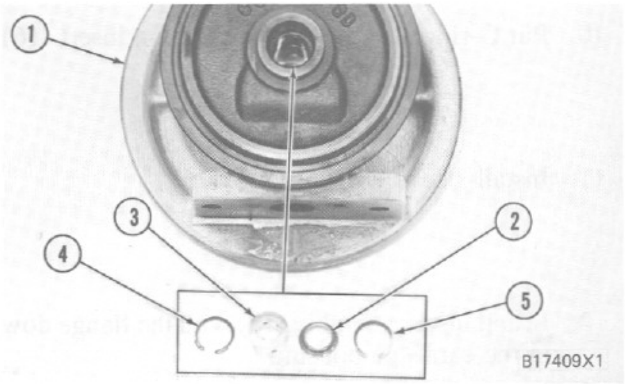
18. Remove bearing (25), sleeve (24) and the lower snap ring.



ASSEMBLE TURBOCHARGER (SCHWITZER 4TF555)

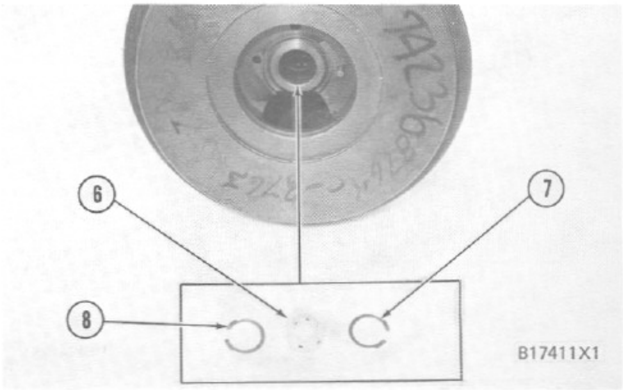
	Tools Needed	A	B	C	D
1P1863	Snap Ring Pliers	1			
1P1852	Snap Ring Pliers		1		
8S2328	Dial Test Indicator Group			1	
9S6343	Fixture Assembly				1

NOTE: Make sure all of the oil passages in the turbocharger cartridge housing are clean and free of dirt and foreign material. Put clean engine oil on all parts of the cartridge assembly.



1. Install snap ring (4) with tooling (A) in cartridge housing (1).

2. Put sleeve (3) and bearing (2) in position. Install snap ring (5) with tooling (A).

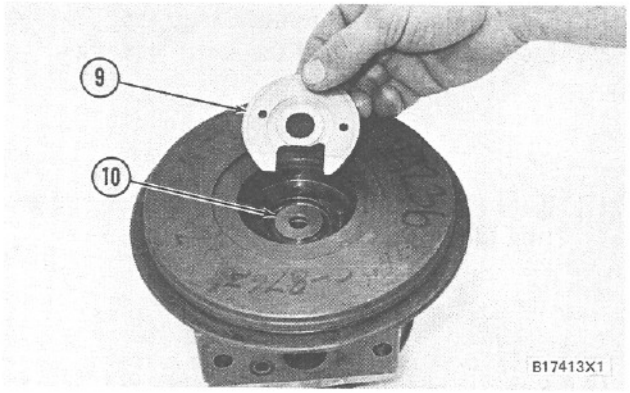


3. Turn the cartridge housing over. Install snap ring (8) with tooling (A).

4. Install sleeve (6) and snap ring (7).

TURBOCHARGER (SCHWITZER 4TF555)

5. Put ring (10) in position in the cartridge housing.

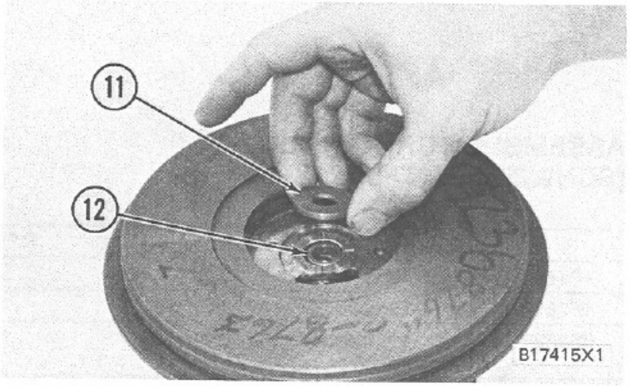


B17413X1

6. Install bearing (9) with grooved side up.

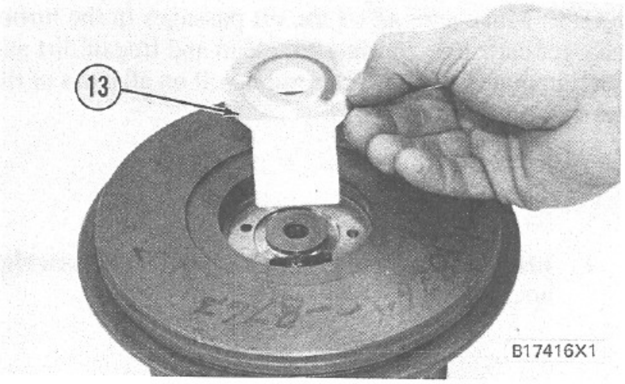
NOTE: Make an alignment of the dowel in the housing with the hole on the right side of the notch.

7. Put sleeve (12) in position. Install ring (11).



B17415X1

8. Put deflector (13) in position as shown.



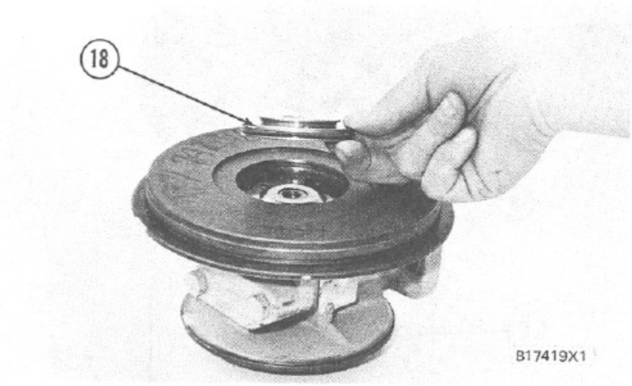
B17416X1

9. Put two seal rings (15) in position on sleeve (14).

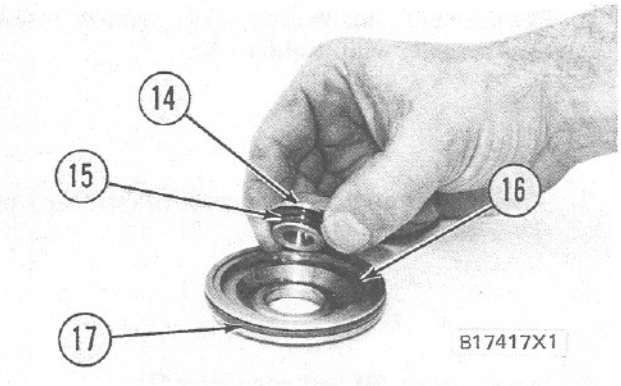
10. Put O-ring seal (17) in position on insert (16).

11. Install sleeve (14) in insert (16).

12. Install insert assembly (18) with the flange down in the cartridge housing.



B17419X1



B17417X1

TURBOCHARGER (SCHWITZER 4TF555)

13. Put O-ring seal (20) in position.

14. Install snap ring (19) with tooling (B).

15. Put shaft assembly (22) in tooling (D).

NOTE: Put 6V2055 High Vacuum Grease in the groove for seal ring (23) at assembly to one half or more of the depth of the groove all the way around the groove.

16. Put seal ring (23) in position on the shaft assembly.

17. Install shroud (21) on the shaft assembly (22).

18. Lightly oil the wheel face that will be under the nut. Put compressor wheel (24) in position.

NOTICE

Do not put a side force on the shaft when the nut is tightened.

19. Install the nut and tighten the nut to a torque of 28 ± 3 N•m (22 ± 2 lb.ft.).

20. Remove the nut. Apply 9S3265 Retaining Compound to the shaft threads.

NOTICE

Do not put a side force on the shaft when the nut is tightened.

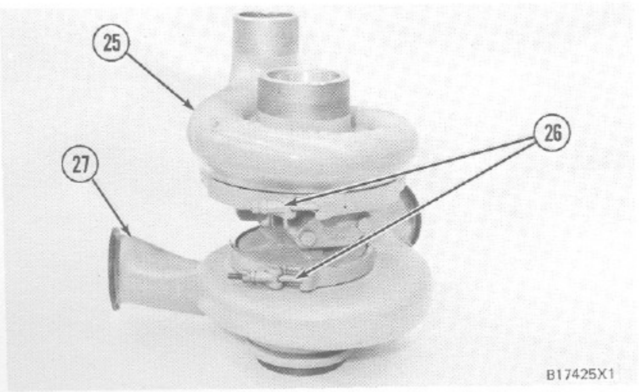
21. Install the nut and tighten it to a torque of 28 ± 3 N•m (22 ± 2 lb.ft.).

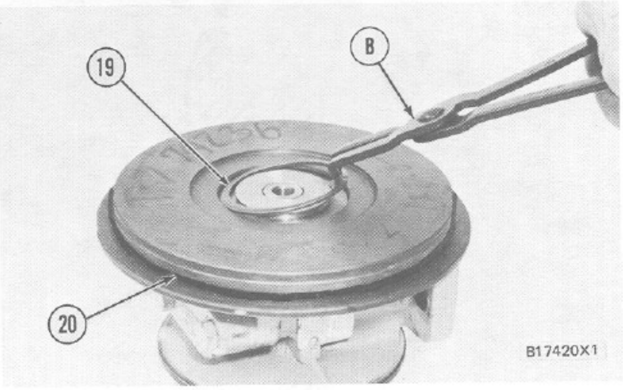
22. Put the cartridge assembly in a vise. Use tooling (C) to check end play. The end play must be 0.08 to 0.15 mm (.003 to .006 in.).

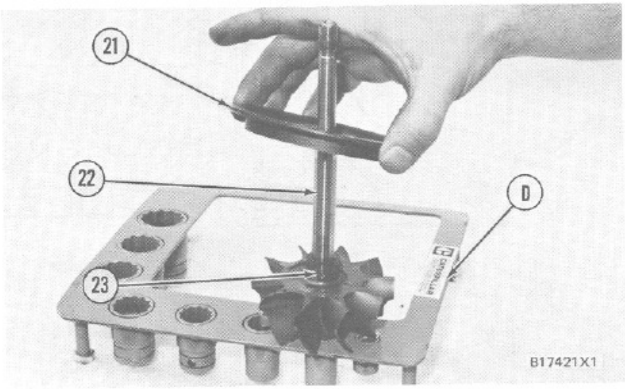
23. Put the cartridge assembly in position on compressor housing (27).

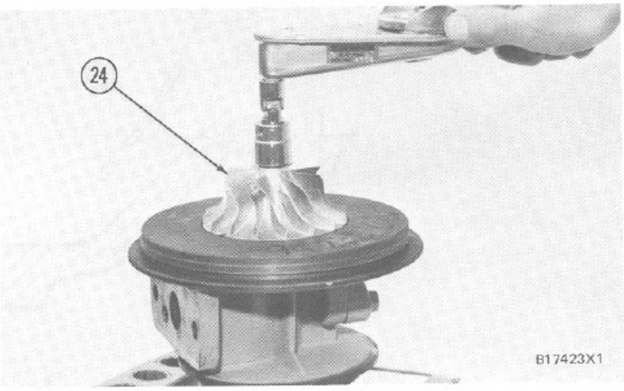
24. Put clamp assemblies (26) and turbine housing (25) in position.

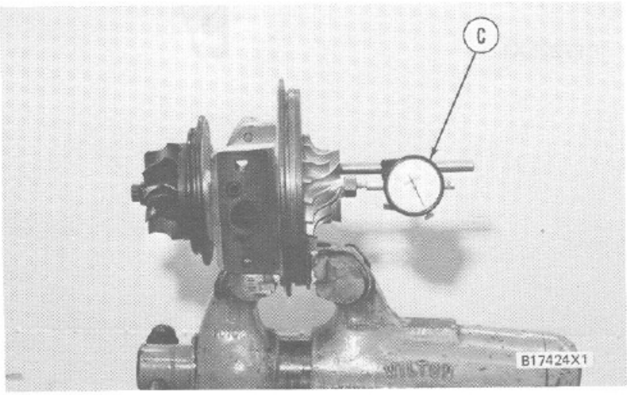
25. Tighten clamp assemblies (26) to a torque of 13.6 N•m (120 lb.in.).



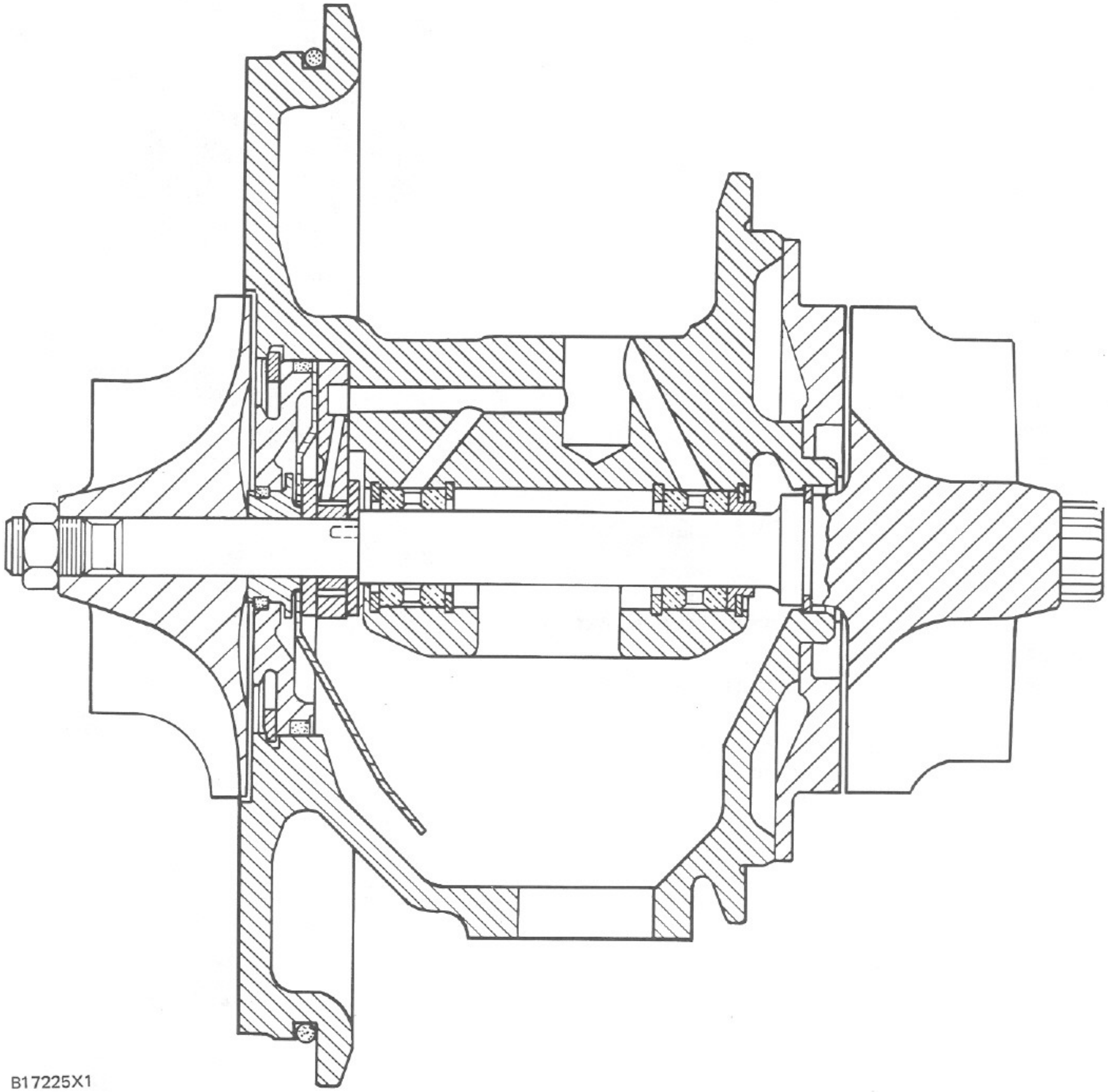








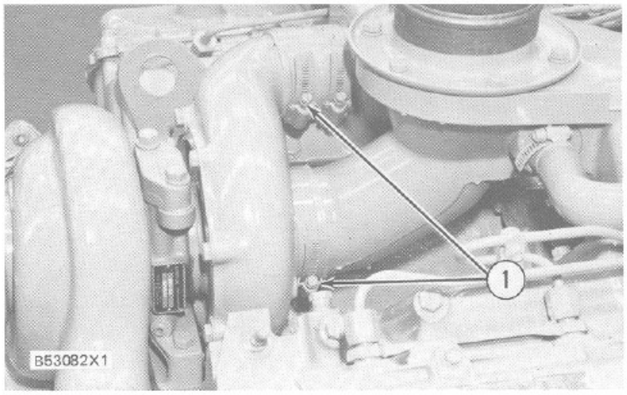
TURBOCHARGER (SWITZER 4TF555)



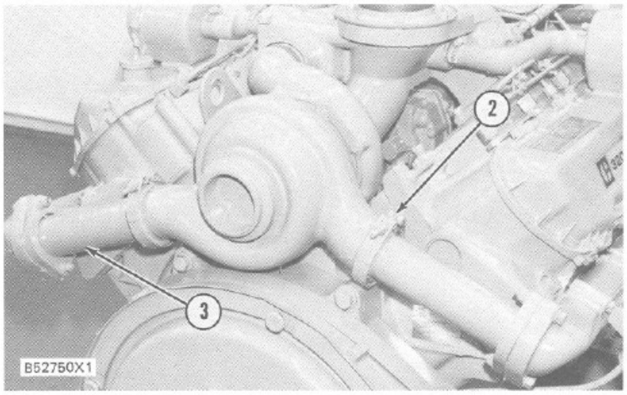
B17225X1

TURBOCHARGER

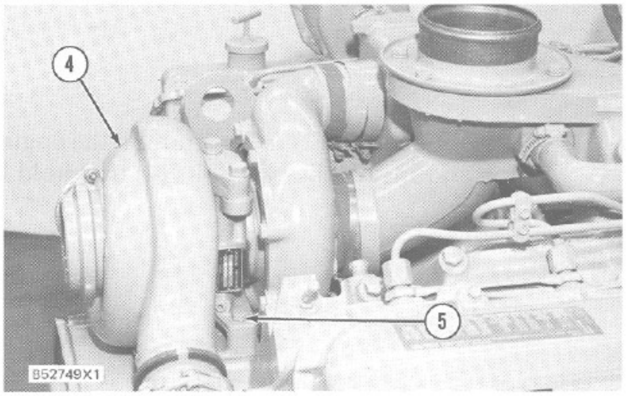
REMOVE TURBOCHARGER 1052-11



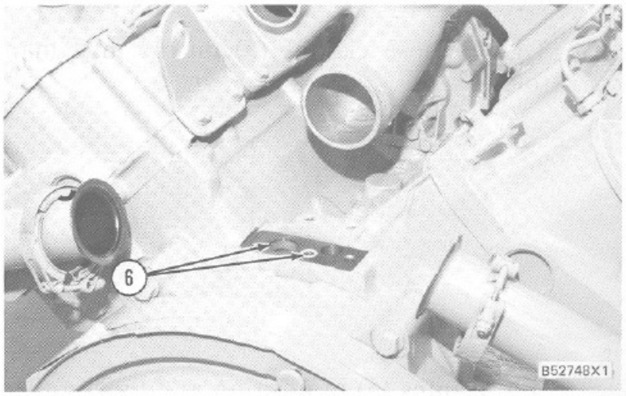
1. Loosen hose clamps (1) on the inlet manifold.


2
3
B52750X1

2. Loosen clamps (2) and slide them back on tubes (3).


4
5
B52749X1

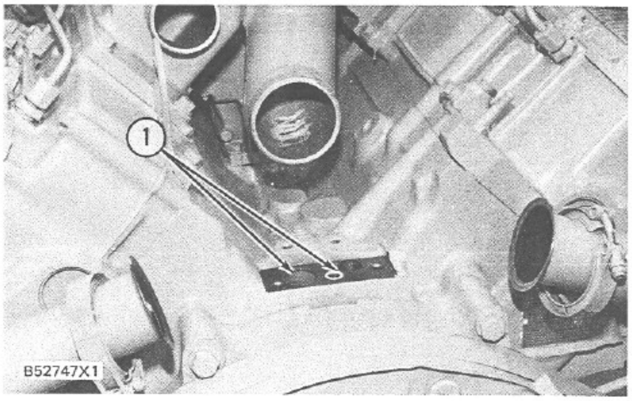
3. Remove two bolts (5) and then remove the turbocharger (4) from the engine block and inlet manifold.



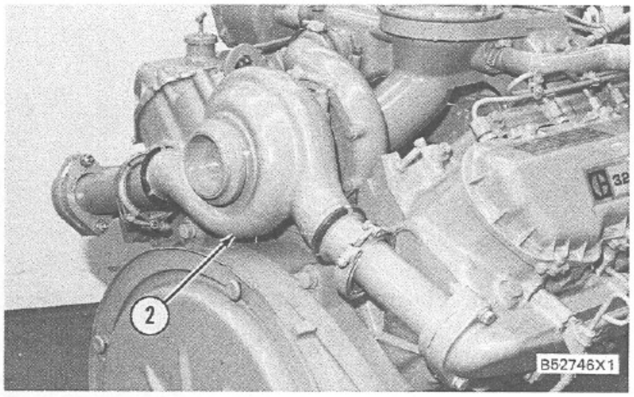
4. Remove the two O-ring seals (6) from the engine block.

TURBOCHARGER

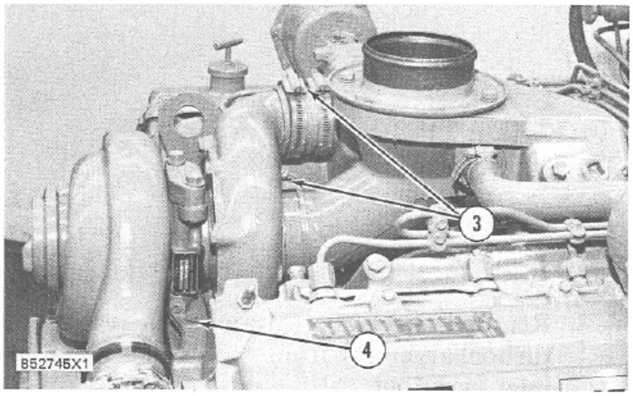
INSTALL TURBOCHARGER 1052-12



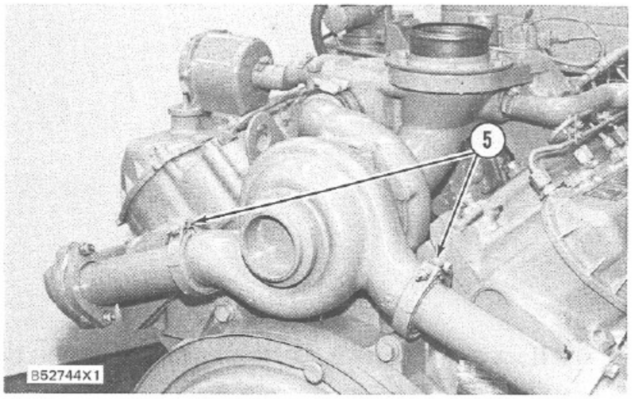
1. Inspect all O-ring seals for wear or damage. Put a small amount of oil on the O-ring seals.



2. Put O-ring seals (1) in position in the engine block.


3
4
B52745X1

3. Put turbocharger (2) in position on the engine block and install the two bolts (4) that hold it.



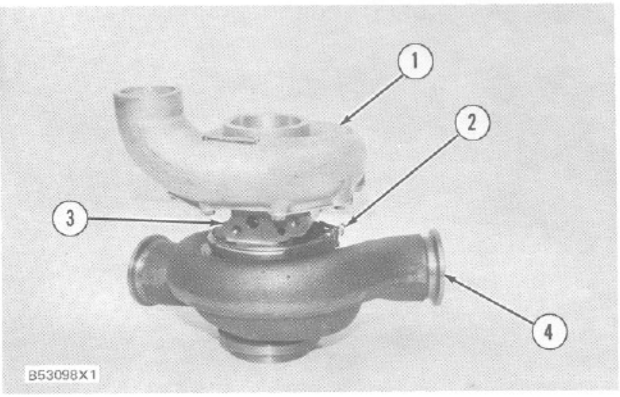
4. Tighten hose clamps (3) on the inlet manifold.

5. Put clamps (5) in position and tighten them.

TURBOCHARGER (AIR RESEARCH TM)

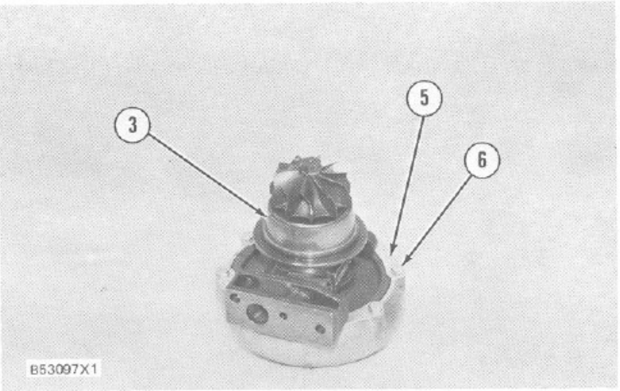
DISASSEMBLE TURBOCHARGER 1052-15

	Tools Needed	A	B	C
9S6343	Fixture Assembly	1		
1P1863	Snap Ring Pliers		1	
5S9566	T-Wrench			1

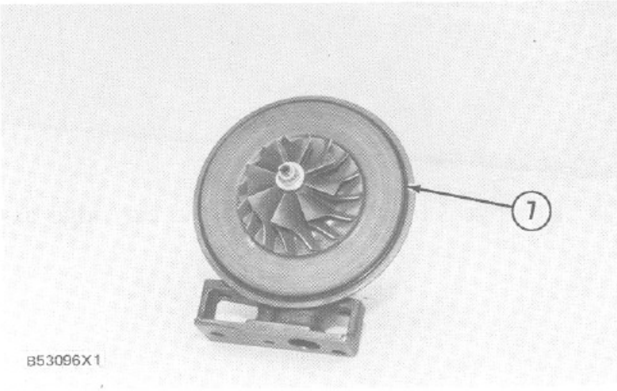


start by:
a) remove turbocharger

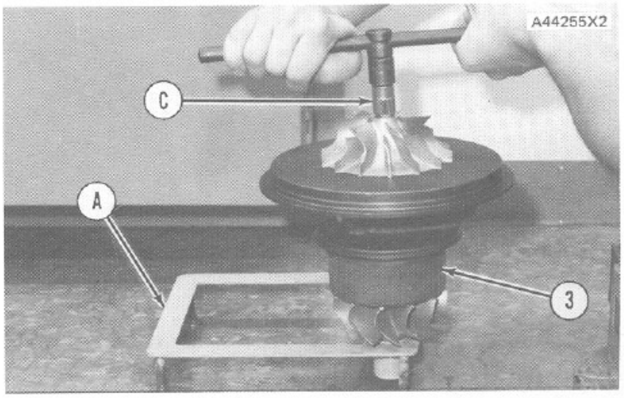
1. Make a mark on compressor housing (1), cartridge assembly (3) and the turbine housing (4) for correct installation.



2. Loosen clamp assembly (2). Remove compressor housing (1) and cartridge assembly (3) from the turbine housing.



3. Remove bolts (6) and plates (5) that hold cartridge assembly in the compressor housing. Remove cartridge assembly (3).

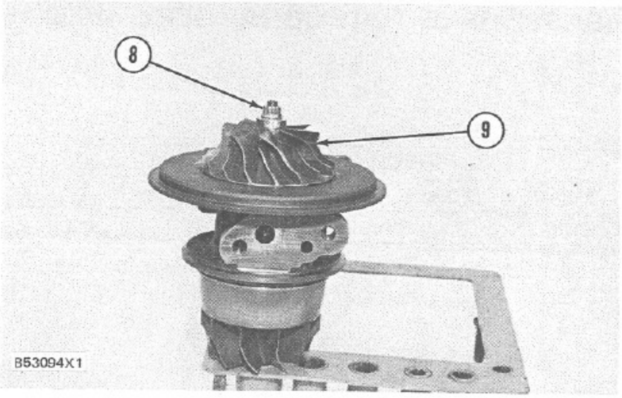


4. Remove O-ring seal (7) from the cartridge assembly.

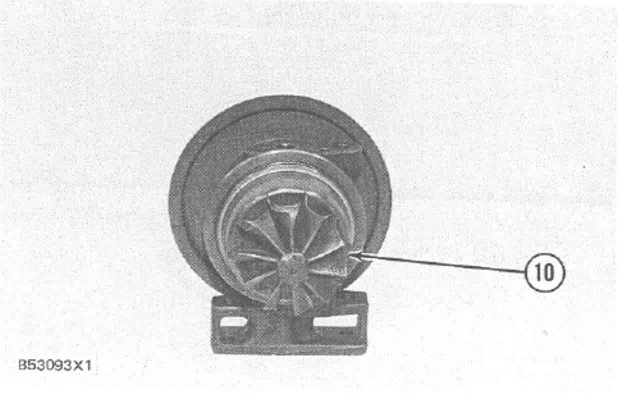
5. Put cartridge assembly (3) in position in tooling (A) and loosen nut on the compressor wheel with tooling (C).

TURBOCHARGER (AIR RESEARCH TM)

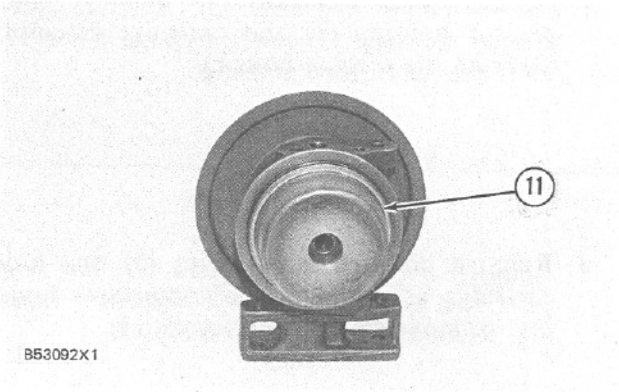
6. Remove nut (8) and the compressor wheel (9).


8
9
B53094X1

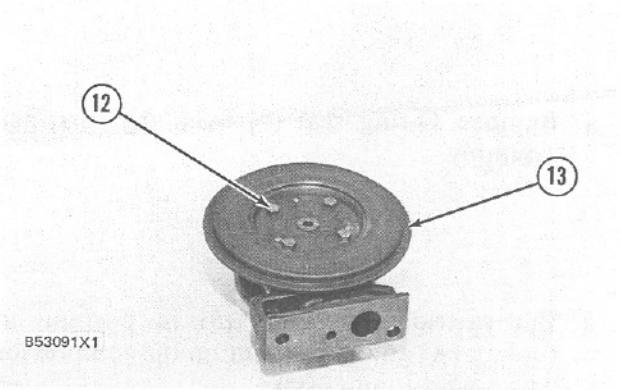
7. Remove shaft and wheel assembly (10) from the cartridge assembly.


10
B53093X1

8. Remove shroud (11) from the cartridge assembly.

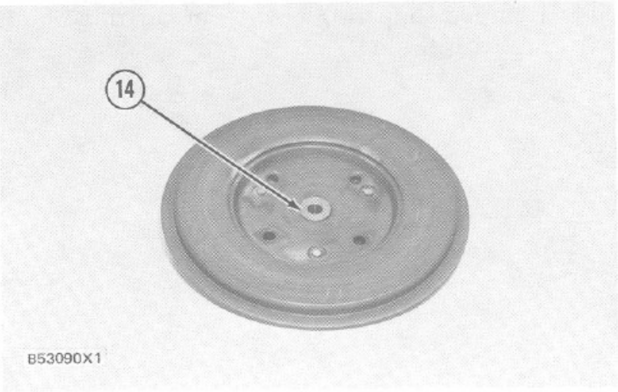

11
B53092X1

9. Remove four bolts (12) and then remove backplate (13) from the cartridge assembly.

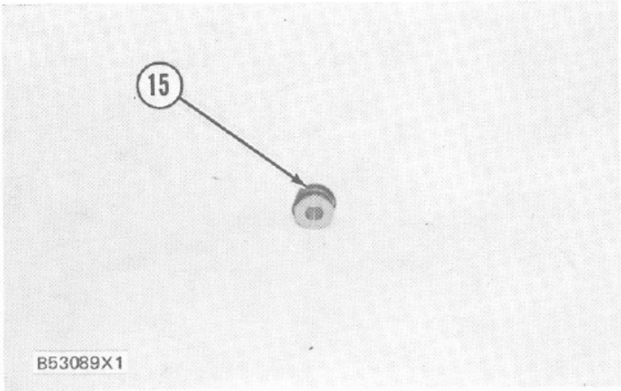

12
13
B53091X1

TURBOCHARGER (AIR RESEARCH TM)

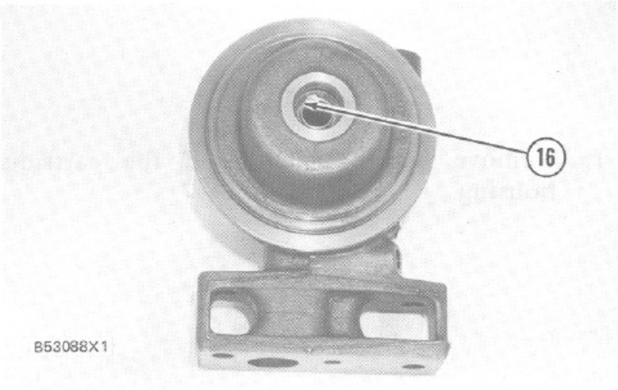
10. Remove spacer (14) from the backplate.


14
B53090X1

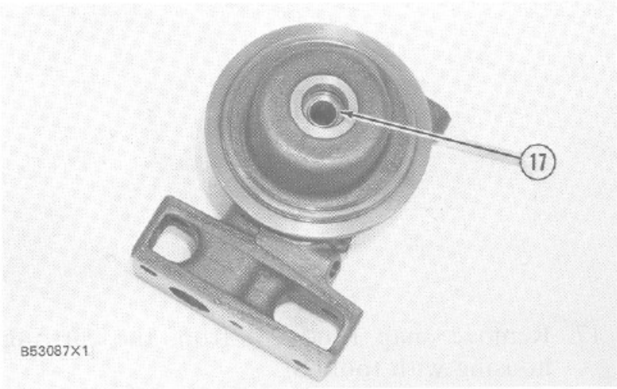
11. Remove two seal rings (15) from the spacer.


15
B53089X1

12. Remove snap ring (16) from cartridge housing with tool (B).

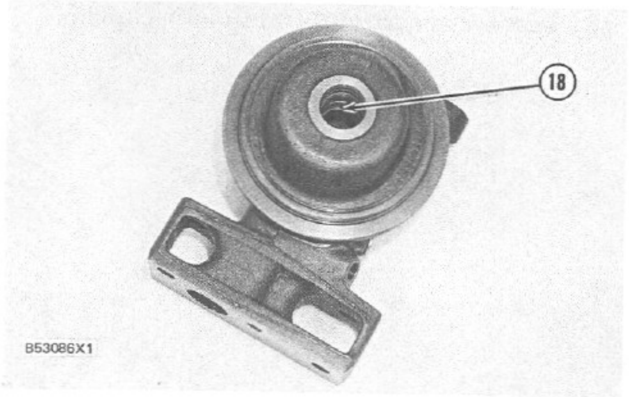

16
B53088X1

13. Remove bearing (17) and rings from the cartridge housing.

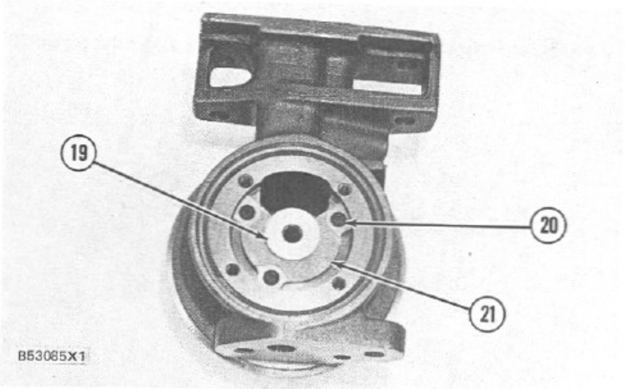

17
B53087X1

TURBOCHARGER (AIR RESEARCH TM)

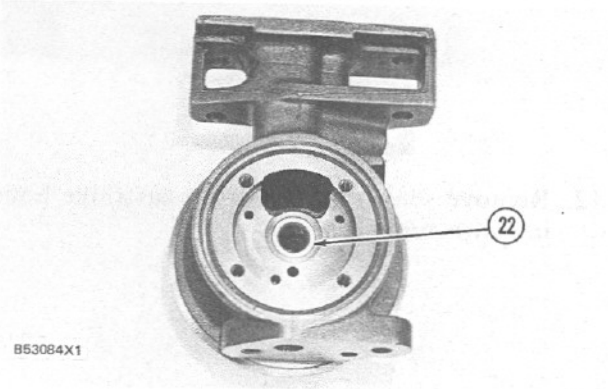
14. Remove snap ring (18) from cartridge housing with tool (B).


18
B53086X1

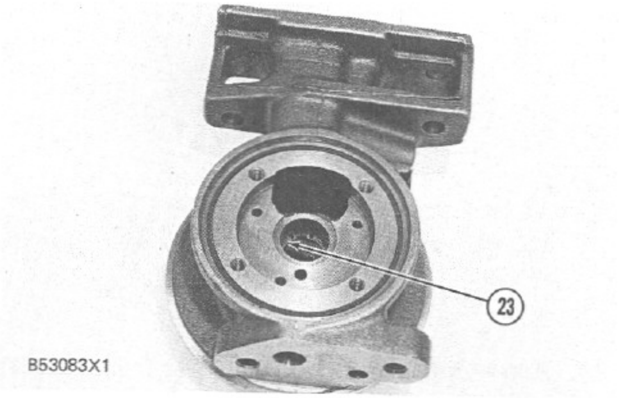
15. Turn the cartridge housing over and then remove screws (20), plate (21) and collar (19).


19
20
21
B53085X1

16. Remove bearing (22) from the cartridge housing.


22
B53084X1

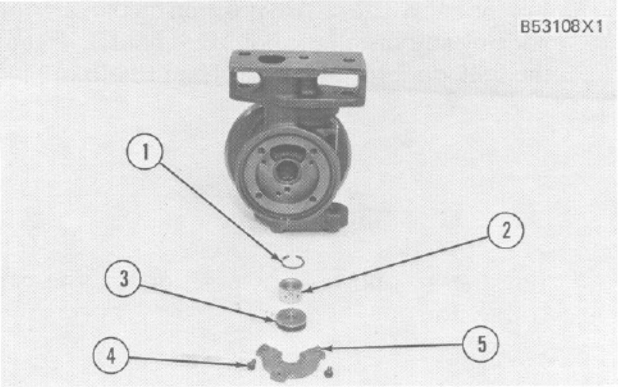
17. Remove snap ring (23) from the cartridge housing with tool (B).


23
B53083X1

TURBOCHARGER (AIR RESEARCH TM)

ASSEMBLE TURBOCHARGER 1052-16

	Tools Needed	A	B	C
1P1863	Snap Ring Pliers	1		
9S6343	Fixture Assembly		1	
8S2328	Indicator Group			1

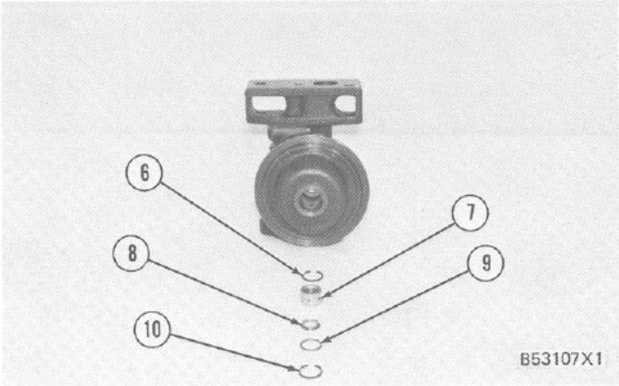


NOTE: Make sure all of the oil passages in the turbocharger cartridge housing are clean and free of dirt and foreign material. Put clean engine oil on all parts of the cartridge assembly.

1. Install snap ring (1) in the cartridge housing with tool (A).

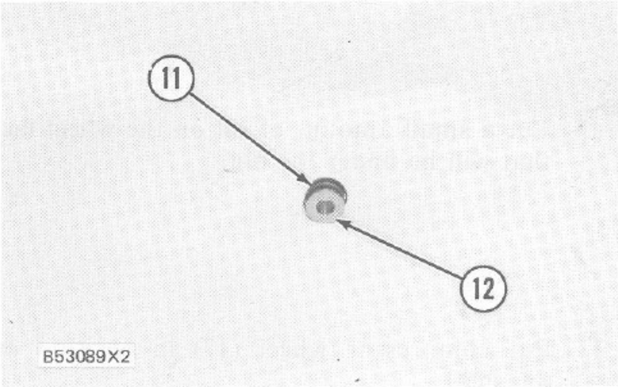
NOTE: Make sure the oil hole in plate (5) is open and clean to prevent a bearing failure.

2. **Install bearing (2), collars (3), plate (5) and screws (4). Tighten the screws to a torque of 2.5 N•m (22 lb.in.).**



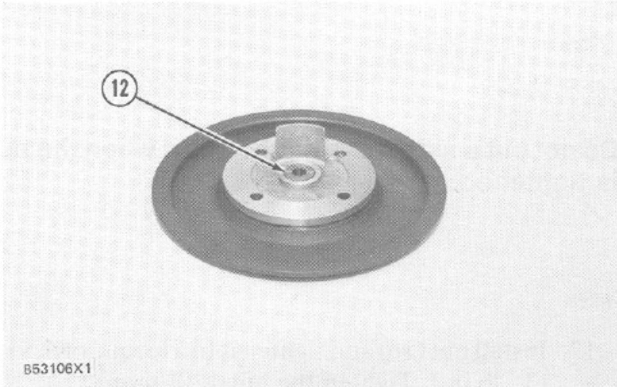
NOTE: Install the rings that hold bearings in position with the round edges of the rings toward the bearings.

3. Turn the cartridge housing over. Install snap ring (6) in the cartridge housing with tool (A). Install bearing (7), ring (8) and ring (9) in the housing. Install snap ring (10) with tool (A).



NOTE: Put 6V2055 High Vacuum Grease in the grooves for seal rings (11) at assembly to one half or more of the depth of the groove all the way around the grooves.

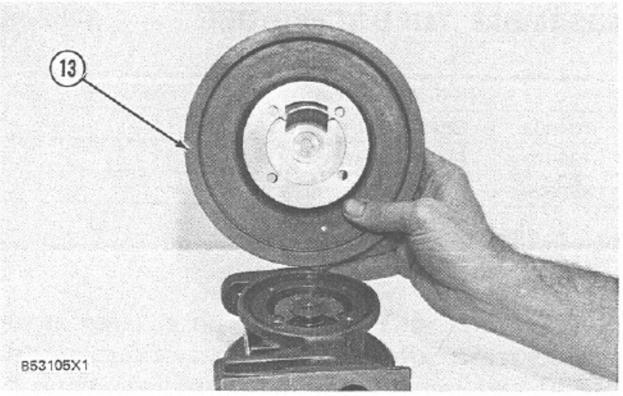
4. Install seal rings (11) on spacer (12).



5. Install spacer (12) in the backplate.

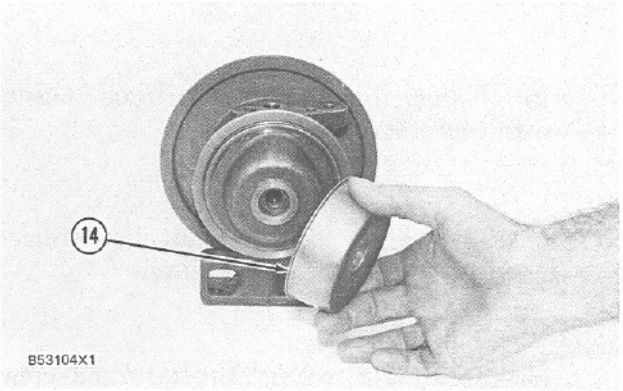
TURBOCHARGER (AIR RESEARCH TM)

6. Put the backplate (13) in position on the cartridge housing and install the bolts that hold it. Tighten the bolts to a torque of 9.5 N•m (84 lb.in.).



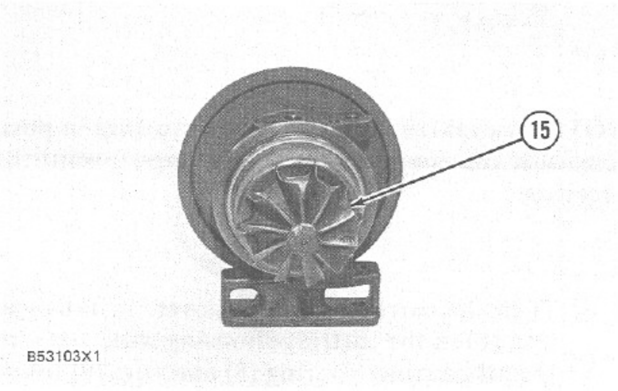
7. Put the shroud (14) in position on the cartridge housing.

8. Install shaft and wheel assembly (15) in the cartridge housing.



9. Put the cartridge assembly in position in tooling (B).

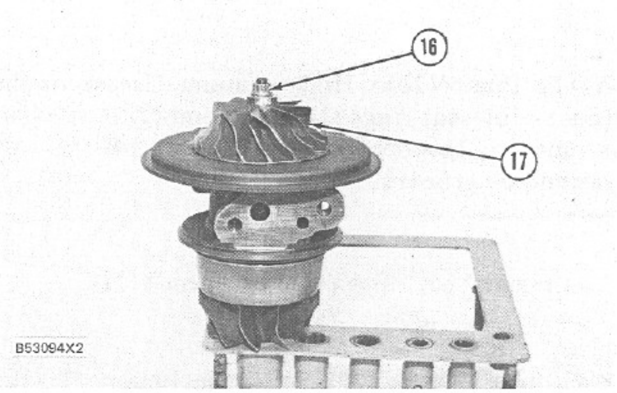
10. Put a small amount of oil on the wheel face that will be under the nut.



11. Put compressor wheel (17) in position on the shaft.

NOTICE

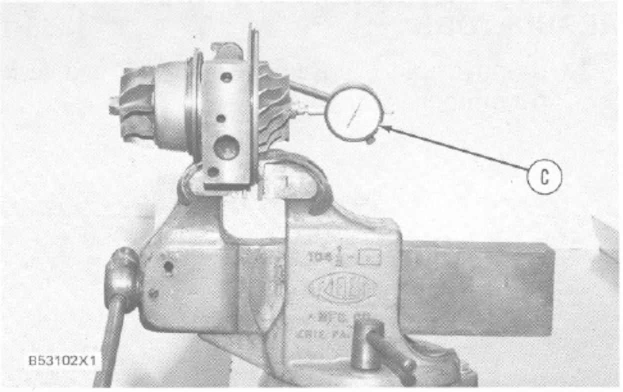
Do not put a side force on the shaft when the nut is tightened.



12. Install nut (16) and tighten it to a torque of 4 N•m (35 lb.in.). Tighten the nut 120° more.

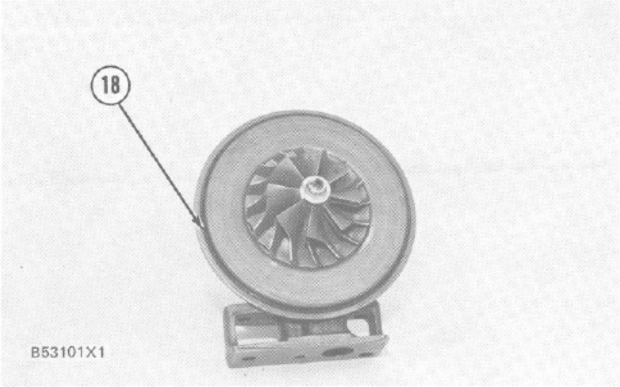
TURBOCHARGER (AIR RESEARCH TM)

13. Put the cartridge assembly in a vise. Use tool group (C) to check end play. The end play must be 0.051 to 0.081 mm (.0020 to .0032 in.).



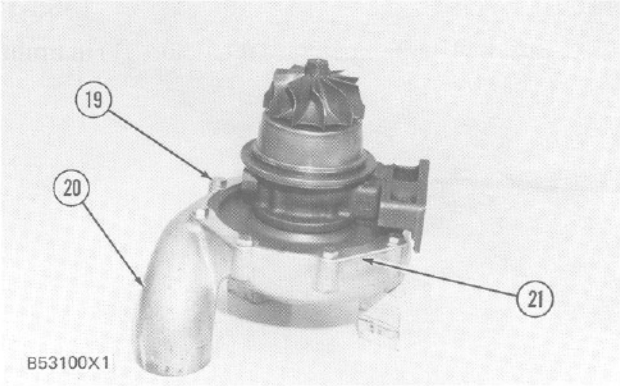
B53102X1

14. Put a small amount of oil on O-ring seal (18) and then install it on the cartridge housing.



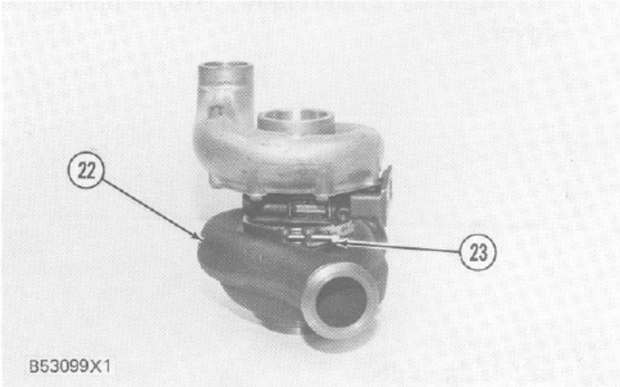
B53101X1

15. Put the cartridge housing on the compressor housing (20) and install the plates (21) and bolts (19).



B53100X1

16. Put the turbine housing (22) in position on the cartridge housing and install the clamp (23) that holds it. Tighten the clamp to a torque of 14 ± 1 N•m (120 ± 12 lb.in.).



B53099X1

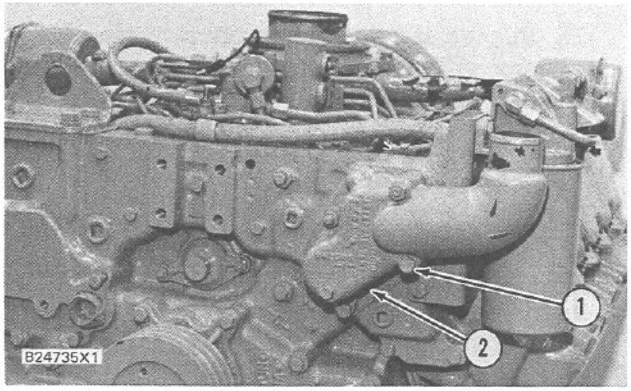
end by:

a) install turbocharger

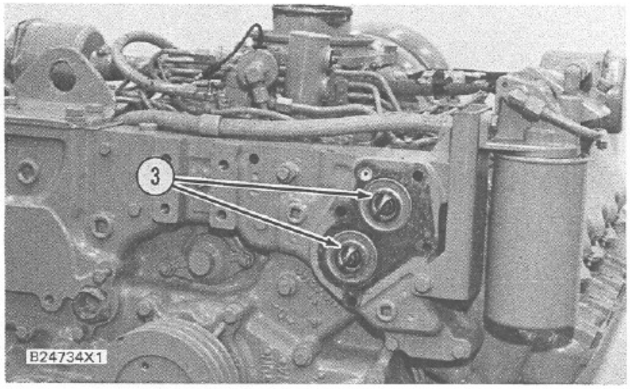
WATER TEMPERATURE REGULATORS

REMOVE WATER TEMPERATURE REGULATORS 1355-11

1. Remove bolts (1). Remove elbow (2) and gasket from timing gear cover.

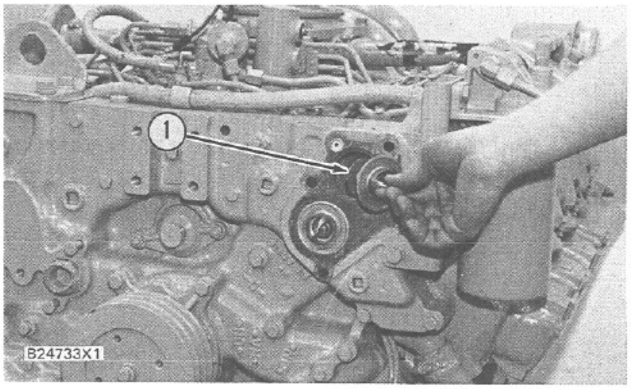


2. Remove water temperature regulators (3) from timing gear cover.

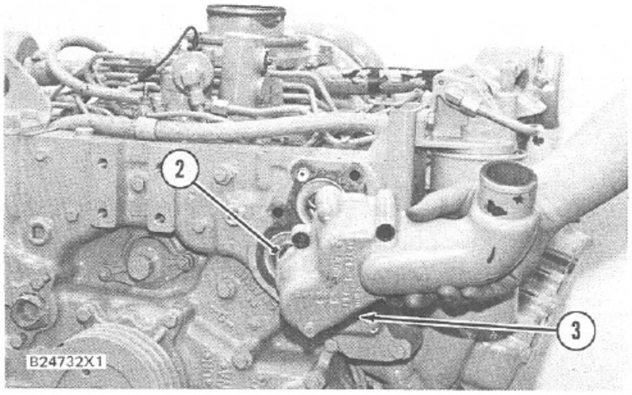


INSTALL WATER TEMPERATURE REGULATORS 1355-12

1. Install water temperature regulators (1) in timing gear cover as shown.



2. Install gasket (2) and elbow (3) to the timing gear cover.



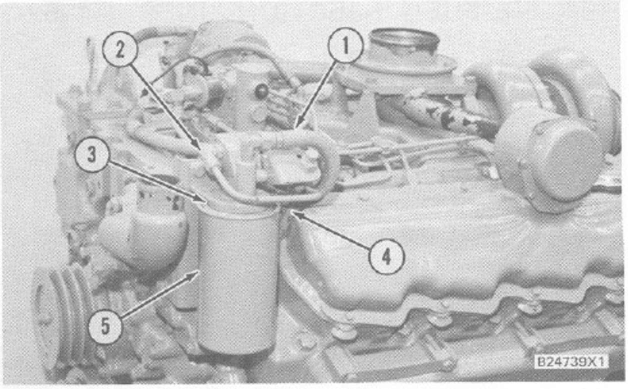
3. Install the bolts.

FUEL FILTER AND BASE

REMOVE FUEL FILTER AND BASE 1262-11

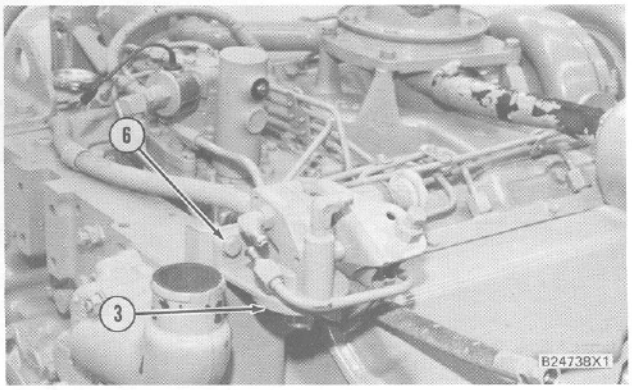
	Tools Needed	A
2P8250	Strap Wrench	1

1. Remove fuel filter element (5) from fuel filter base (3) with tool (A).



2. Disconnect fuel lines (1), (2) and (4) from fuel filter base.

3. Remove two bolts (6) and two nuts and remove fuel filter base from the bracket.

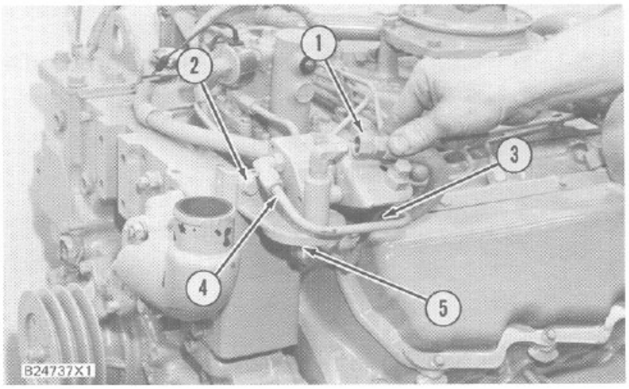


INSTALL FUEL FILTER AND BASE 1262-12

	Tools Needed	A
2P8250	Strap Wrench	1

1. Install fuel filter base (5) and nuts and bolts (2).

2. Connect fuel lines (1), (3) and (4) to fuel filter base (5).

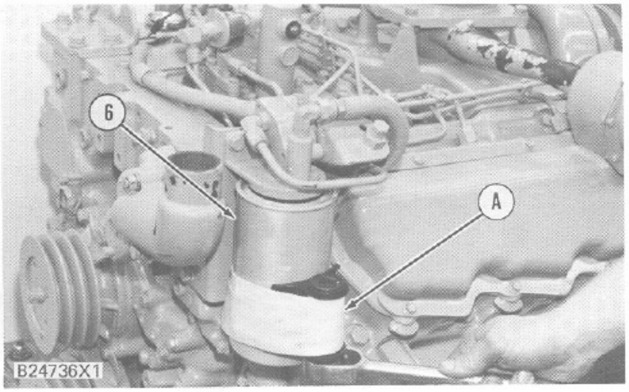


3. Clean filter base surface. Be sure old gasket is removed.

4. Put clean diesel fuel on the filter gasket.

5. Install fuel filter element (6) with tool (A).

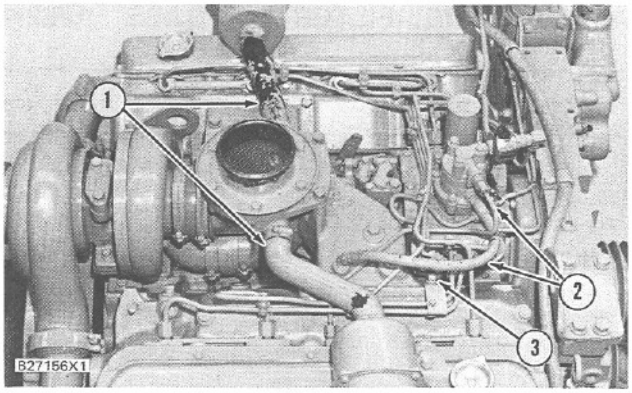
6. Tighten ½ to ¾ turn after filter gasket makes contact with the base.



FUEL INJECTION LINES

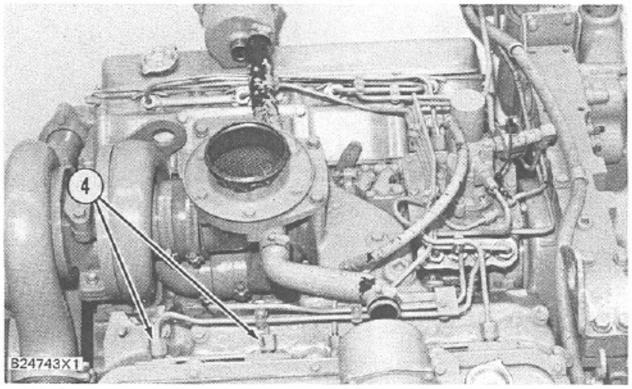
REMOVE FUEL INJECTION LINES 1252-11

1. Disconnect lines (1) and (2).


1
2
3
B27156X1

2. Remove bolt (3) from the bracket.

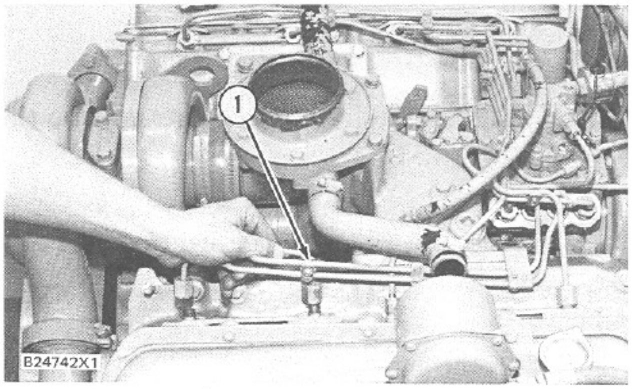
3. Loosen nuts (4) at the cylinder head and the fuel injection pump. Remove the fuel lines and install caps or plugs on all openings.



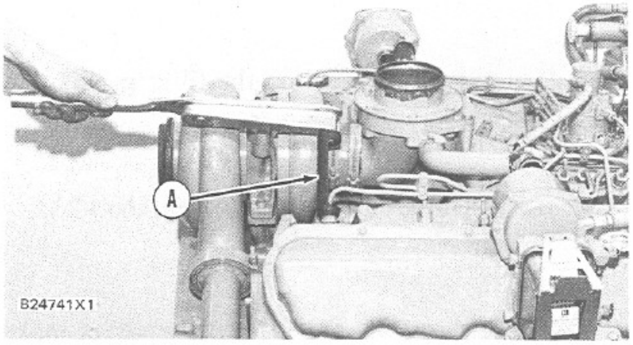
INSTALL FUEL INJECTION LINES 1252-12

	Tools Needed	A
5P144	Socket	1

1. Put fuel injection lines (1) in position.

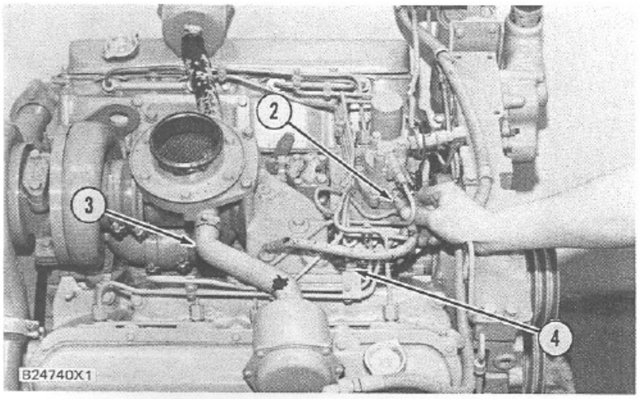


2. Tighten the nuts with tooling (A) to a torque of 40 ± 7 N•m (30 ± 5 lb.ft.).



3. Connect two lines (3) and line (2).

4. Install bolt (4) in the bracket.


2
3
4
B24740X1

FUEL INJECTION PUMP HOUSING AND GOVERNOR

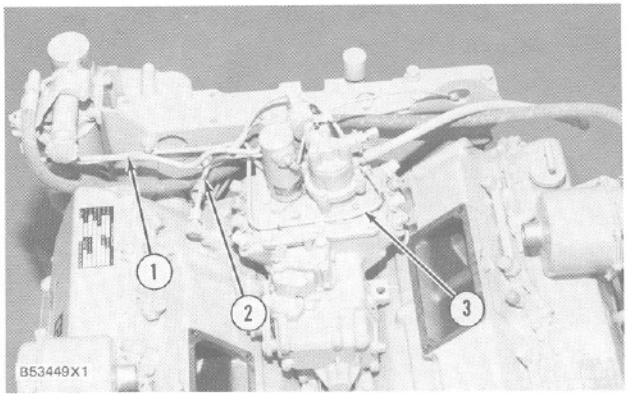
REMOVE FUEL INJECTION PUMP HOUSING AND GOVERNOR 1286-11

	Tools Needed	A	B
3P1544	Timing Pin	1	
6V4069	Body Group		1

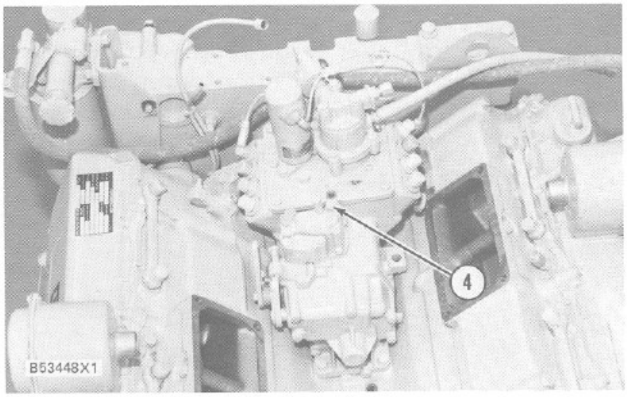
start by:
a) remove fuel lines
b) remove air inlet manifold

NOTICE

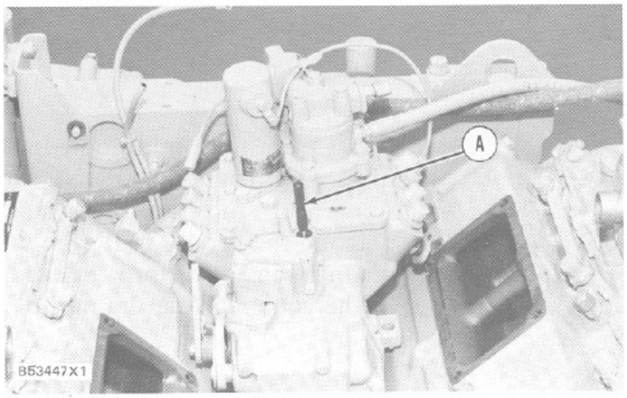
Make sure all foreign material is kept out of the inlet manifold openings.



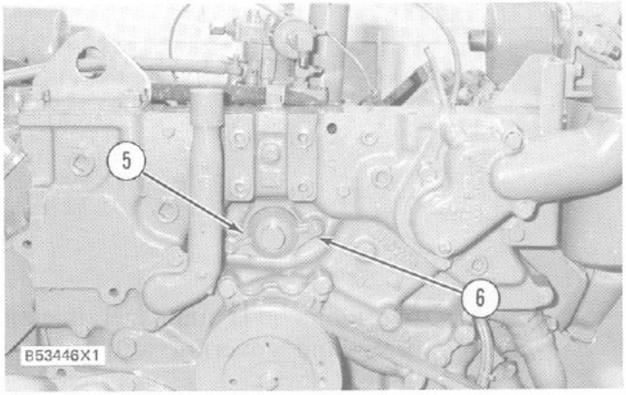
1. Remove fuel lines (1), (2) and (3) from the engine.



2. Remove bolt (4).



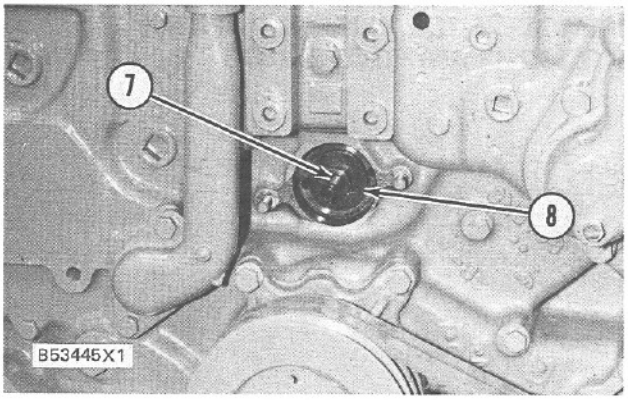
3. Install tool (A). Turn the crankshaft clockwise (as seen from the front of the engine) until the timing pin drops into the groove (slot) in the injection pump camshaft. For the correct timing procedure, see TESTING AND ADJUSTING, FUEL SYSTEM ADJUSTMENTS.



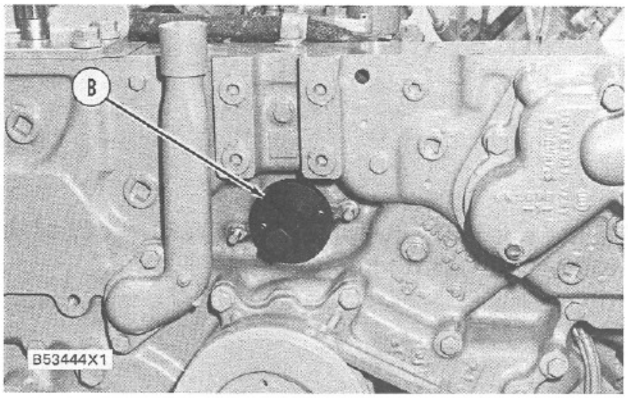
4. Remove nuts (6), then remove the tachometer cover (5).

FUEL INJECTION PUMP HOUSING AND GOVERNOR

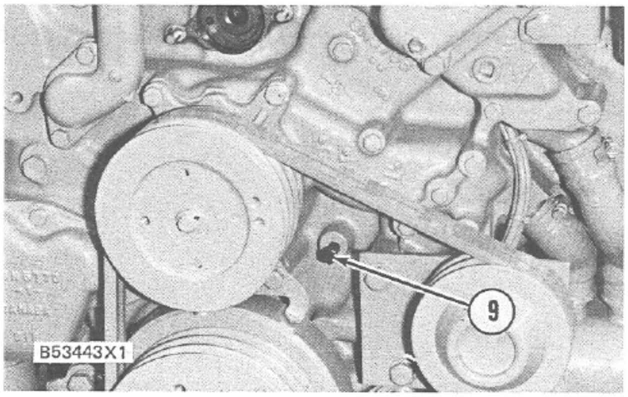
5. Remove tachometer drive shaft (7) and washer (8).



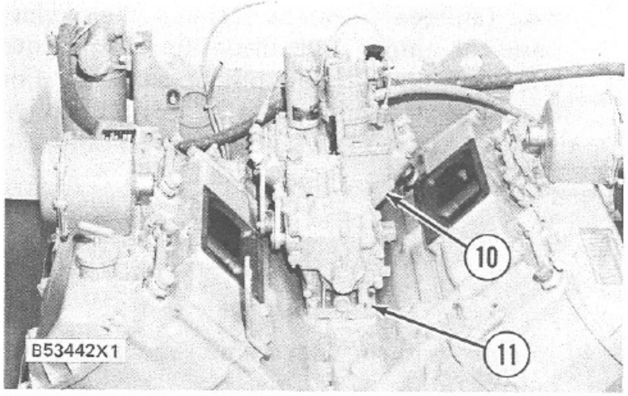
6. Install tooling (B) into the camshaft drive gear for the fuel injection pump. Turn tooling (B) until the drive gear is free of the shaft. Remove tooling (B).



7. Remove the plug from the timing hole in the front cover and install a 5/16"-18 NC bolt (9) 2-1/2 in. long. Turn the crankshaft (clockwise as seen from the front of the engine) until bolt (9) can be installed into the timing gear and is in the center of the timing hole.



8. Remove two bolts (11) and fuel injection pump housing and governor (10) from the engine.



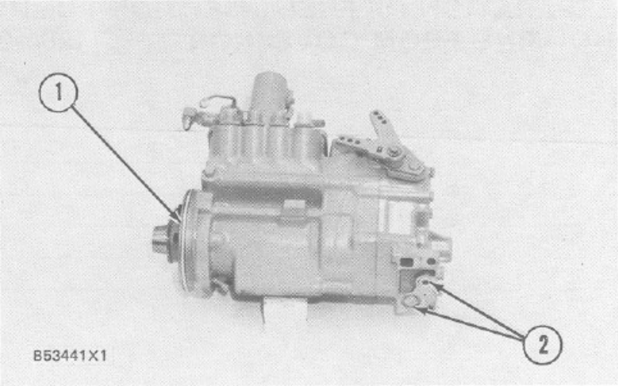
FUEL INJECTION PUMP HOUSING AND GOVERNOR

INSTALL FUEL INJECTION PUMP HOUSING AND GOVERNOR 1286-12

	Tools Needed	A
3P1544	Timing Pin	1

1. Make sure O-ring seals (1) and (2) are in position.
2. Put fuel injection pump housing and governor (3) in position and install the bolts that hold it.
3. Install the washer (5) and tachometer drive shaft (4). Tighten the shaft to a torque of 149 ± 14 N•m (110 ± 10 lb.ft.).
4. Check the timing, see FUEL SYSTEM ADJUSTMENTS in TESTING AND ADJUSTING.
5. Install the tachometer cover (6) and the nuts (7) that hold it in place.
6. Remove tool (A) from the pump and install bolt (10).
7. Install fuel lines (8), (9), (11) and the clips that hold them.

end by:
a) install air inlet manifold
b) install fuel lines



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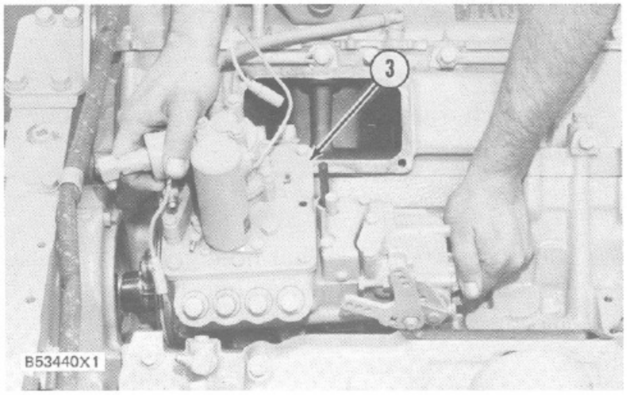

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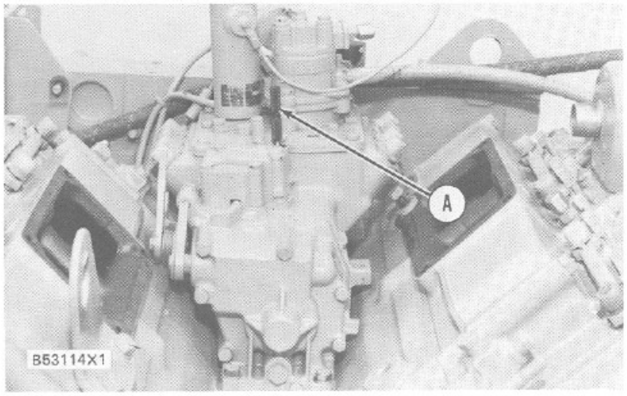

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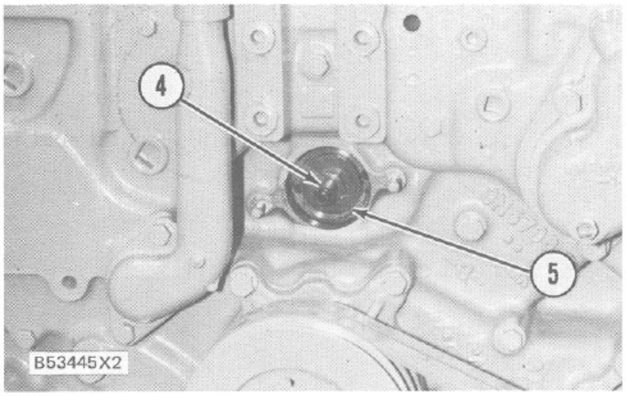

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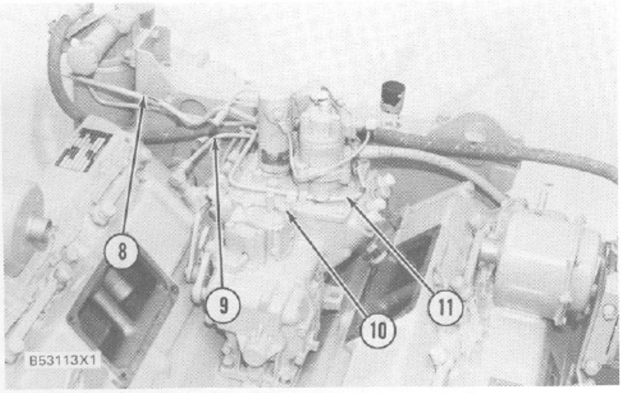

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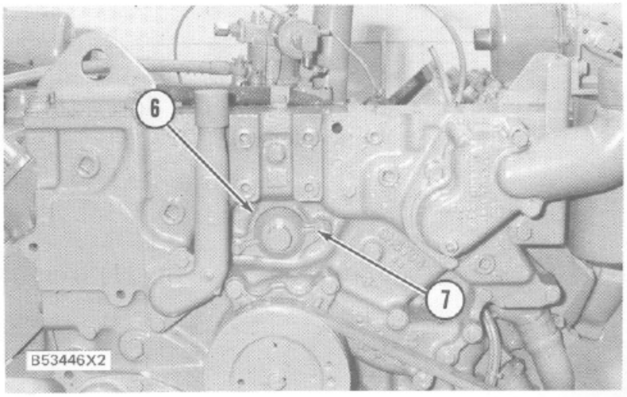
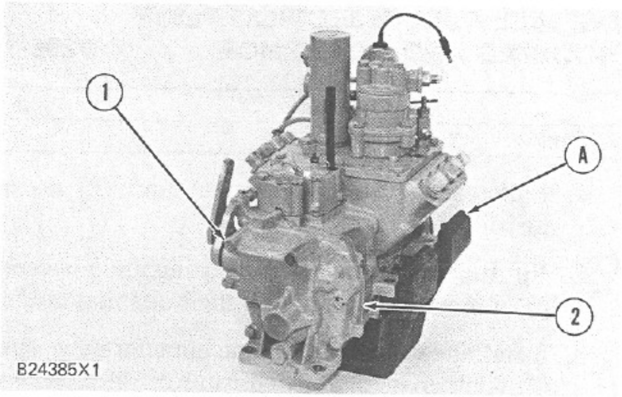


B53446X2

FUEL INJECTION PUMP HOUSING AND GOVERNOR

SEPARATION OF FUEL INJECTION PUMP HOUSING FROM GOVERNOR 1264-29

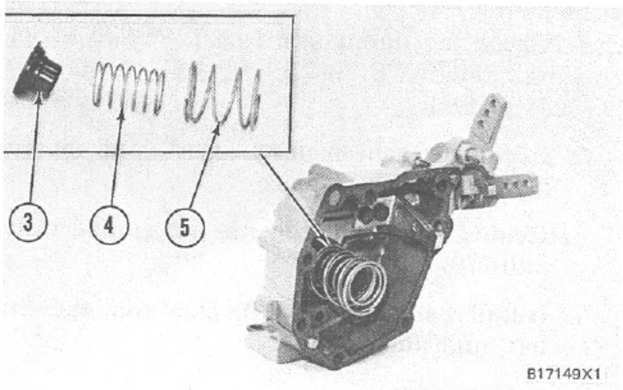
	Tools Needed	A	B	C	D
2P8315	Bracket Assembly	1			
1P1855	Snap Ring Pliers		1		
5P302	Bar			1	
3P1544	Timing Pin				1



B24385X1

start by:
a) remove fuel injection pump housing and governor

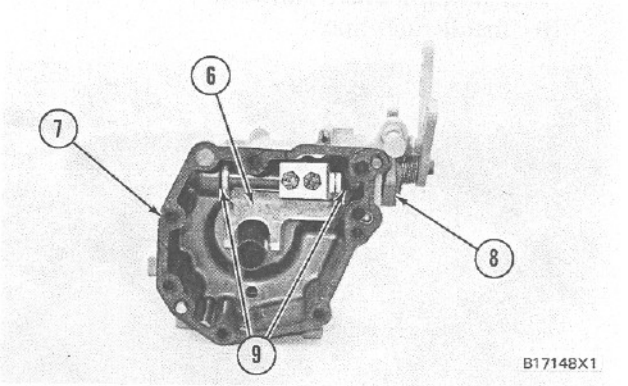
1. Install the fuel injection pump housing on tool (A).



B17149X1

2. Remove bolts (1) that hold governor housing assembly (2) to the fuel injection pump housing.

3. Remove governor housing assemblies (2) and gasket.

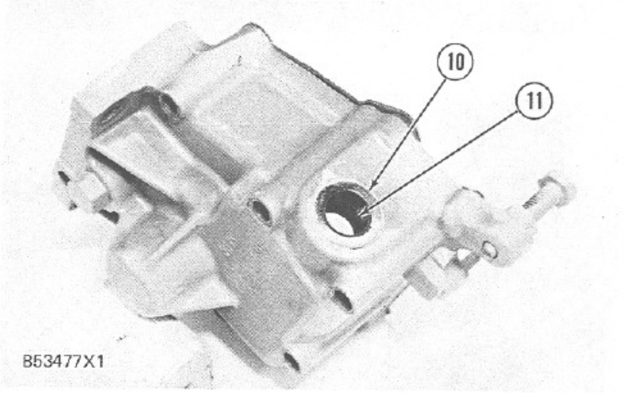


B17148X1

4. Remove two springs (5) and (4) and seat (3).

5. Remove the springs from the seat.

6. Remove the bolts from the shaft.



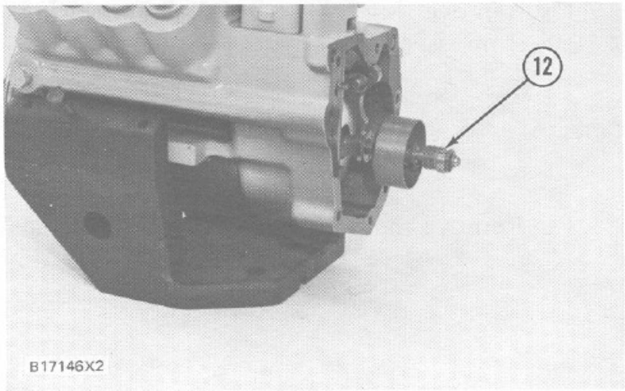
B53477X1

7. Remove shaft assembly (8), lever (6) and washers (9) from housing (7).

8. Remove seal (10) and bushing (11) from the governor housing.

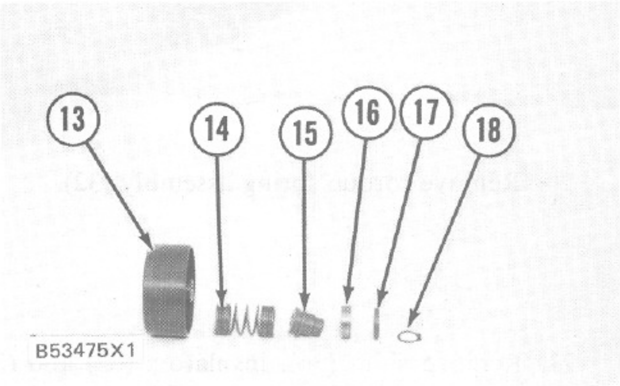
FUEL INJECTION PUMP HOUSING AND GOVERNOR

9. Remove piston assembly (12).


12
B17146X2

10. Remove spring (14) from seat (13) and seat (15).

11. Remove snap ring (18) from seat (15) with tooling (B).


13
14
15
16
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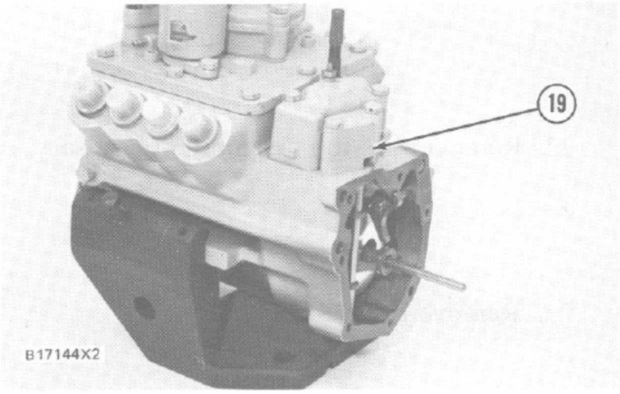
18
B53475X1

12. Remove ring (17) and spool (16) from the seat.

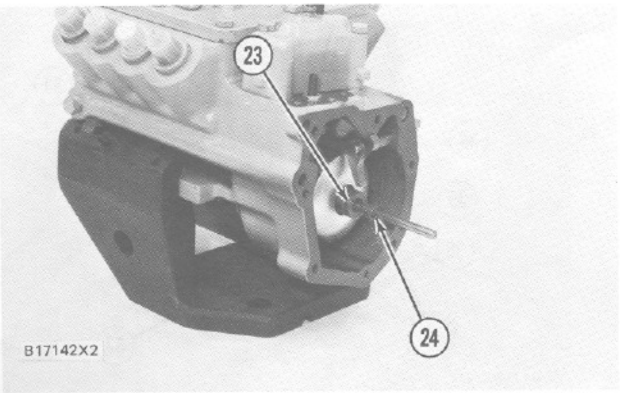
13. Remove the bolts and cover (19).


19
B17144X2

14. Remove shaft (21) and lever (22).

15. Remove O-ring seal (20) from the shaft.

16. Remove spring (23) and riser assembly (24).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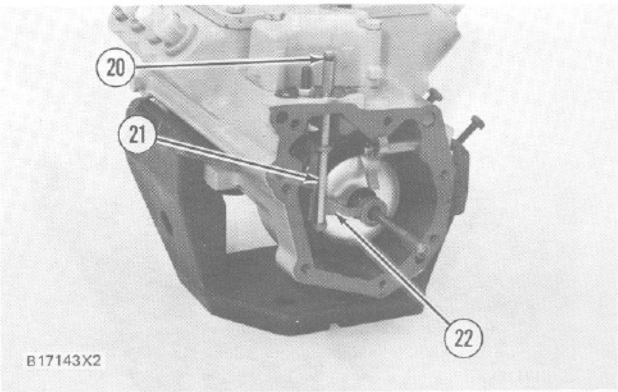
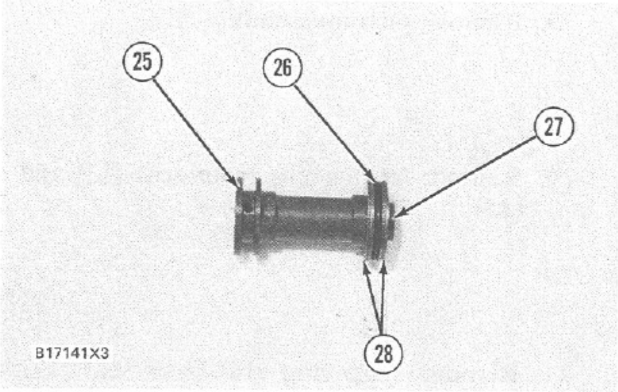
B17142X2


20
21
22
B17143X2

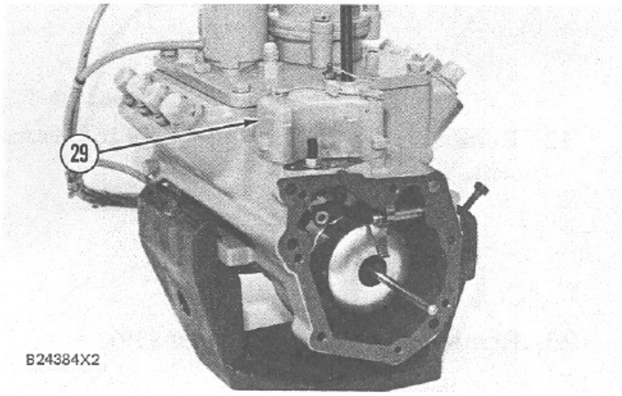
FUEL INJECTION PUMP HOUSING AND GOVERNOR

17. Remove ring (27), races (28) and bearing (26) from riser (25).



B17141X3

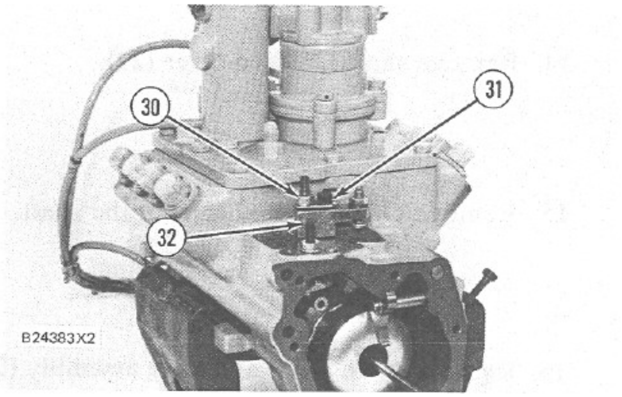
18. Remove the bolts, cover (29) and the gasket.



B24384X2

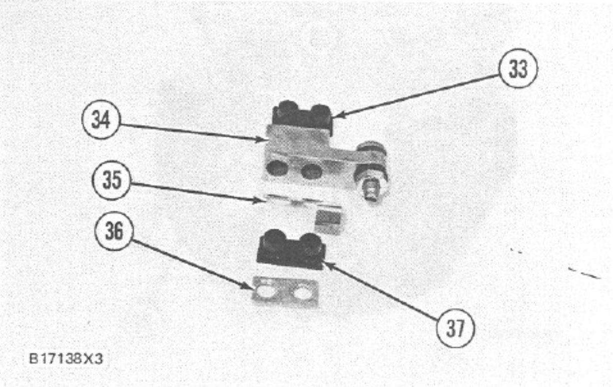
19. Remove nut (30) and bolt (31).

20. Remove torque spring assembly (32).



B24383X2

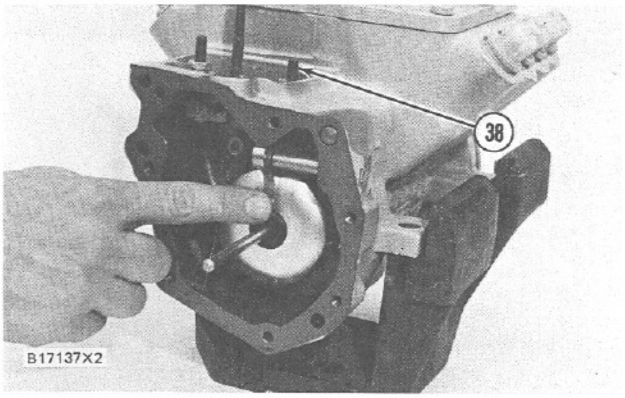
21. Remove shim (36), insulators (33) and (37), and contact (35) from bar (34).



B17138X3

22. Remove the stop assembly if necessary.

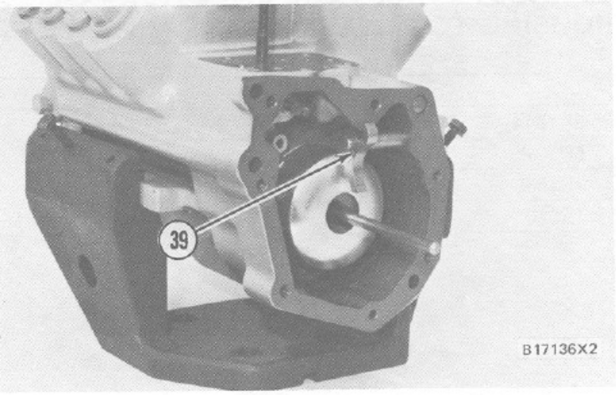
23. Remove rod (38).



B17137X2

FUEL INJECTION PUMP HOUSING AND GOVERNOR

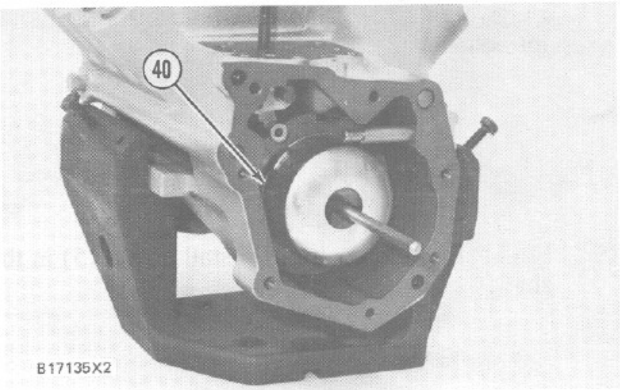
24. Remove lockring (39) and the lever.


39
B17136X2

NOTICE

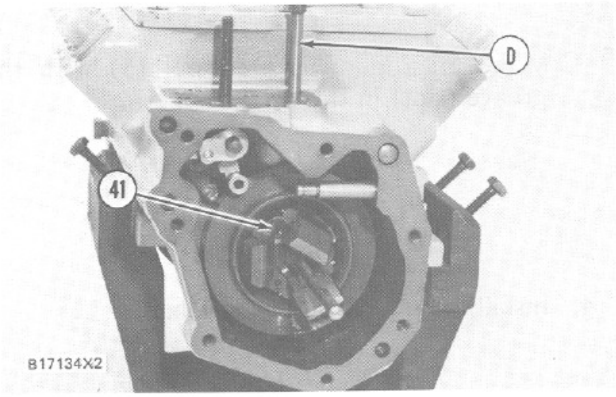
Pull on the shield only a small amount in each location so it will not have distortion or damage. The metal of the shield is moved (staked) around the camshaft and the shield can be damaged when it is removed. If the shield has damage, use a new part for replacement.

25. Remove shield (40) from the camshaft with tooling (C).


40
B17135X2

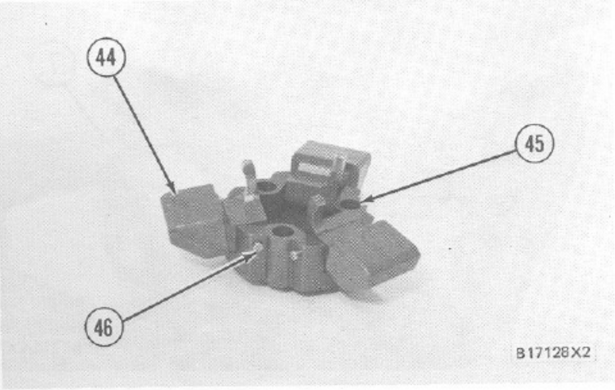
26. Install tooling (D) into the camshaft.

27. Remove three bolts (41) and the carrier assembly.


D
41
B17134X2

28. Remove dowel (42) from rod (43). Remove rod (43).

29. Remove pins (46) and weight (44) from carrier (45).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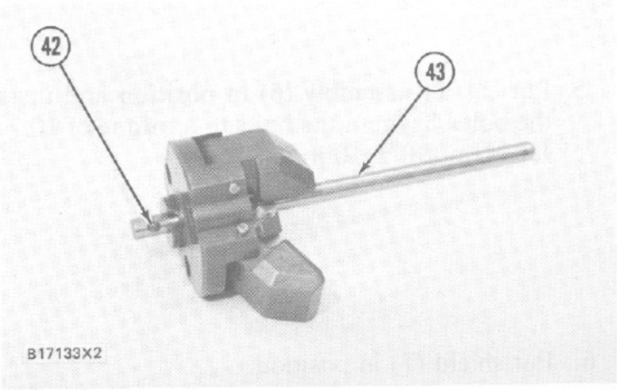
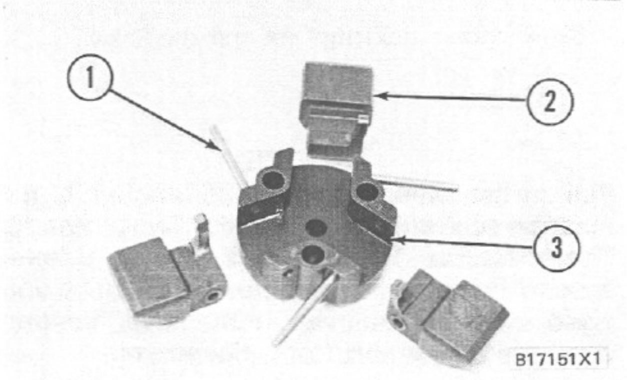
45
46
B17128X2


42
43
B17133X2

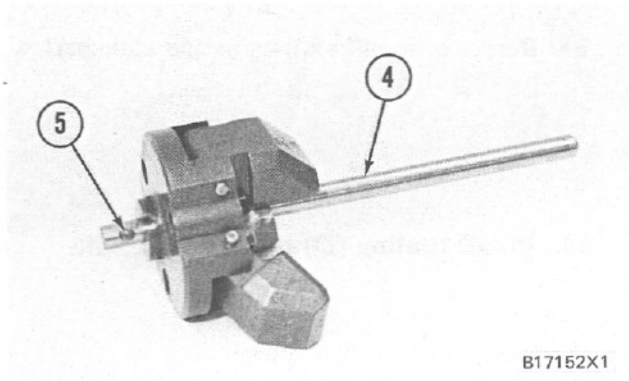
FUEL INJECTION PUMP HOUSING AND GOVERNOR

CONNECTION OF FUEL INJECTION PUMP HOUSING TO GOVERNOR 1264-29

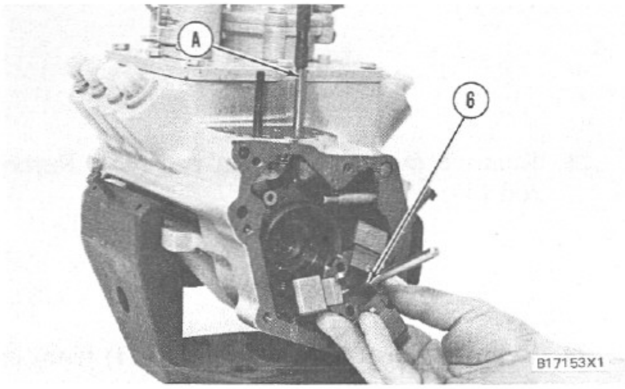
	Tools Needed	A	B	C	D
3P1544	Timing Pin	1			
5P301	Driver		1		
1P1855	Snap Ring Pliers			1	
1P510	Driver Group				1



1. Put weights (2) in position and install pins (1) into carrier (3).

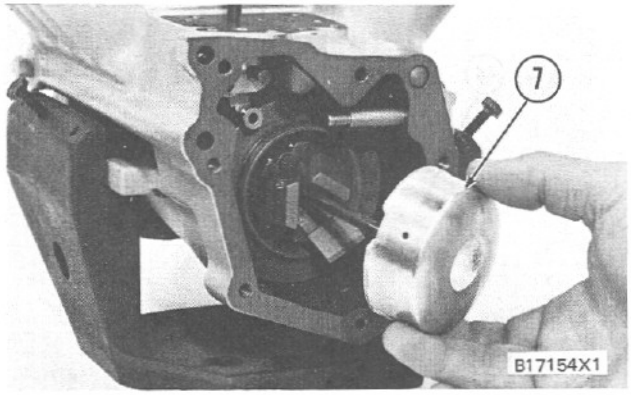


2. Put shaft (4) in position. Install dowel (5) in the shaft.



3. Make an alignment of dowel (5) with the groove (slot) in the carrier.

4. Install tooling (A) in the camshaft.

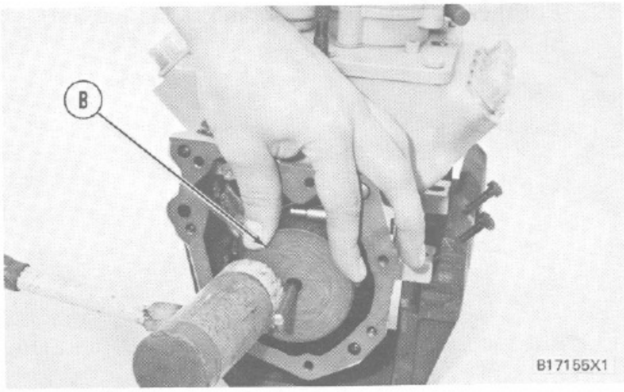


5. Put carrier assembly (6) in position and install the bolts. Tighten the bolts to a torque of 10.2 ± 1.1 N•m (90 ± 10 lb.in.).

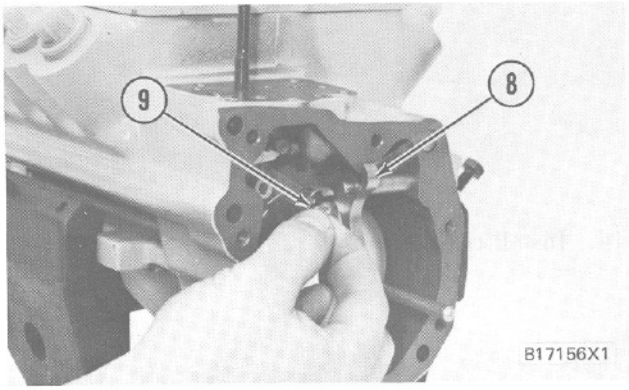
6. Put shield (7) in position.

FUEL INJECTION PUMP HOUSING AND GOVERNOR

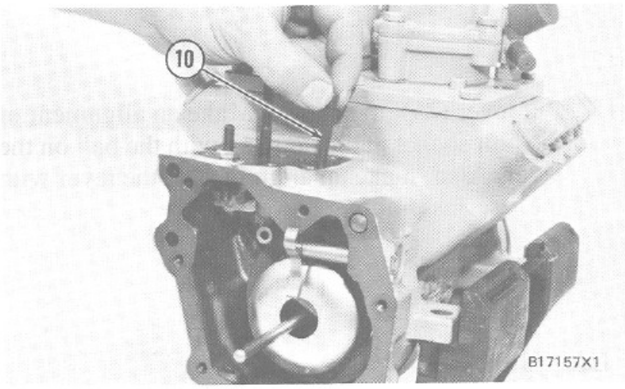
7. Install the shield with tooling (B). Move the metal over on (stake) the shield on to the camshaft in alignment with the groove on the camshaft. Use an 1/8" screwdriver with a taper ground on the bottom edge so the screwdriver fits evenly against the flyweight assembly cover to stake it in two places 180° ± 5° apart.



8. Put lever (8) in position and install lockring (9).

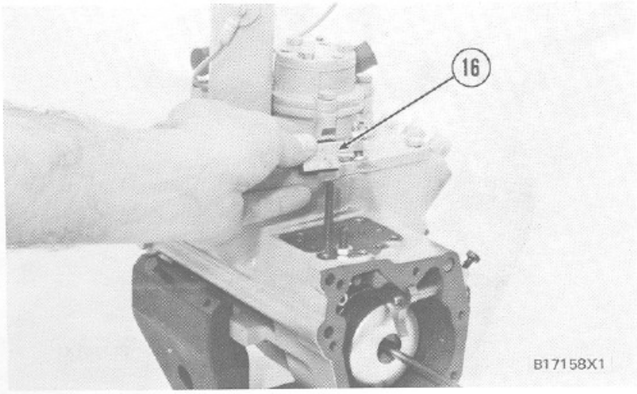

9
8
B17156X1

9. Install pin (10).


10
B17157X1

10. Put contact (13), insulators (11) and (14) and shim (15) in position on bar (12).

11. Install torque spring assembly (16). Install the nut and bolt.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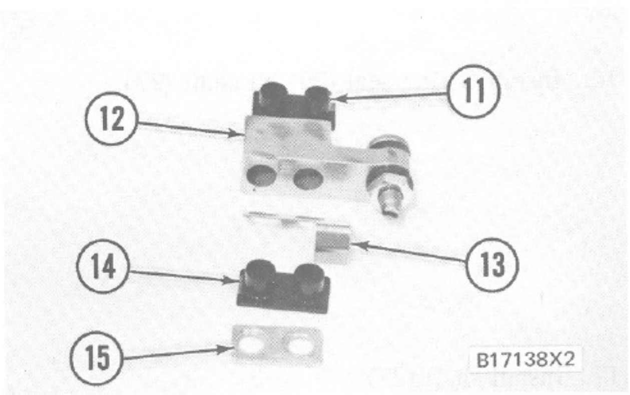
B17158X1


12
11
14
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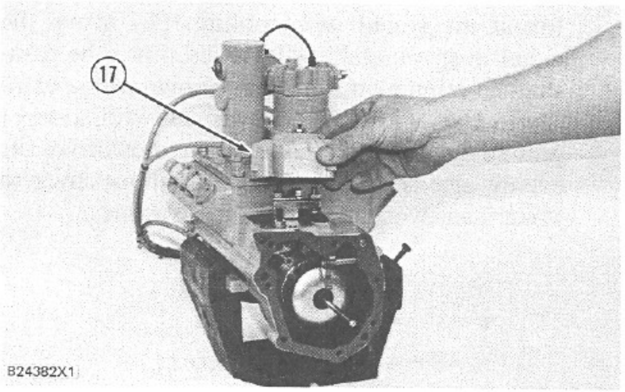
B17138X2

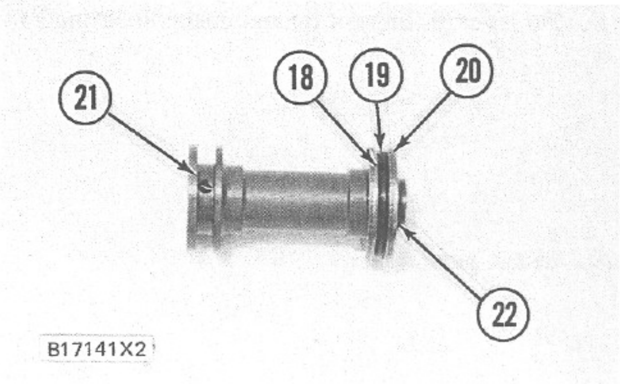
FUEL INJECTION PUMP HOUSING AND GOVERNOR

12. Put the gasket in position and install cover (17) and the bolts.



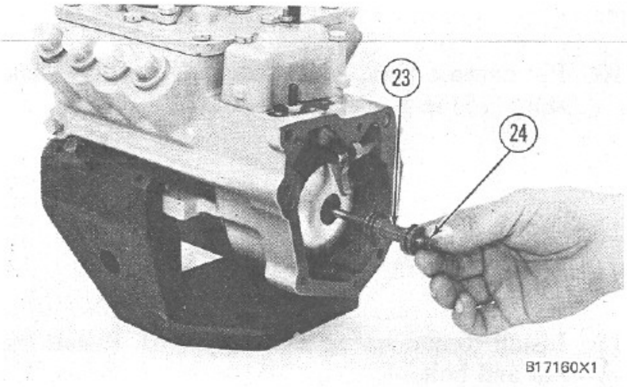
B24382X1

13. Put race (18), bearing (19), race (20) and ring (22) on riser (21).



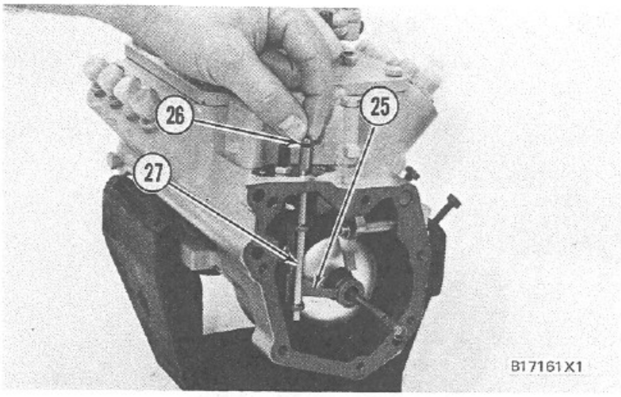
B17141X2

14. Install riser assembly (23) and spring (24).



B17160X1

15. Put lever (25) in position. Make an alignment of the bolt socket in the housing with the ball on the lever. Also, make an alignment of the riser assembly.



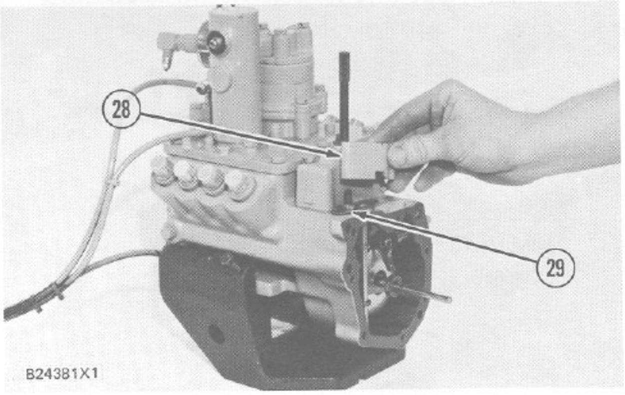
B17161X1

16. Install O-ring seal (26) on shaft (27).

17. Install shaft (27).

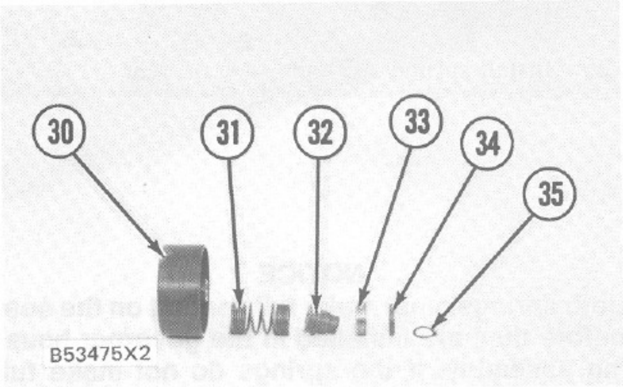
FUEL INJECTION PUMP HOUSING AND GOVERNOR

18. Put gasket (29) in position. Install cover (28) and the bolts.

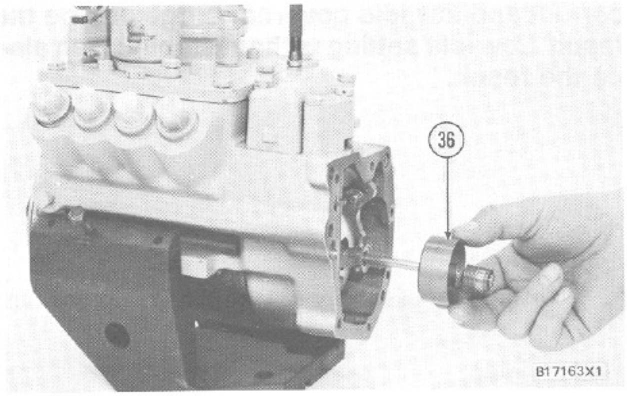


19. Put spool (33) and ring (34) in position and install snap ring (35) with tooling (C) on seat (32).

20. Install spring (31) on seats (30) and (32).

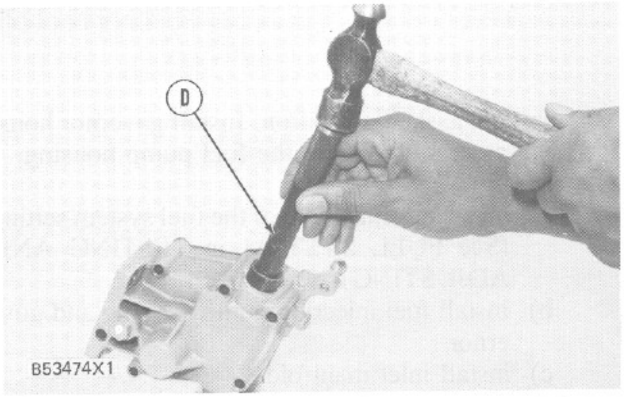


21. Install piston assembly (36).



NOTE: Make a layer on the outside diameter of the seal with 5S1454 Sealant before the seal is installed.

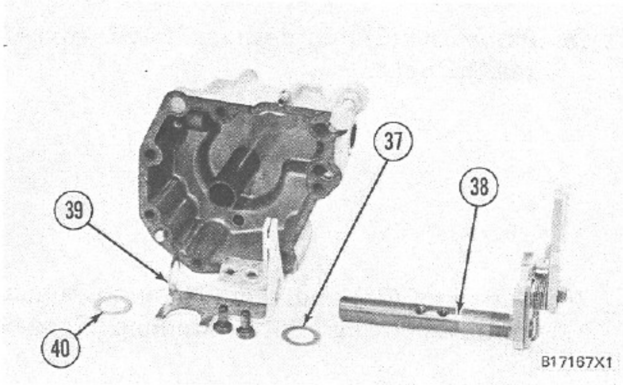
22. Use tooling (D) to install the bushing and seal in the governor housing. Install the seal with the lip of the seal toward the inside of the housing.



23. Remove the excess sealant. Put diesel fuel as a lubricant on the lip of the seal.

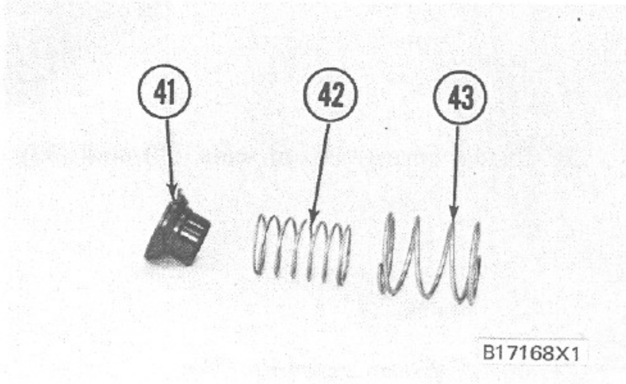
FUEL INJECTION PUMP HOUSING AND GOVERNOR

24. Install shaft assembly (38), washer (37), lever (39) and washer (40).



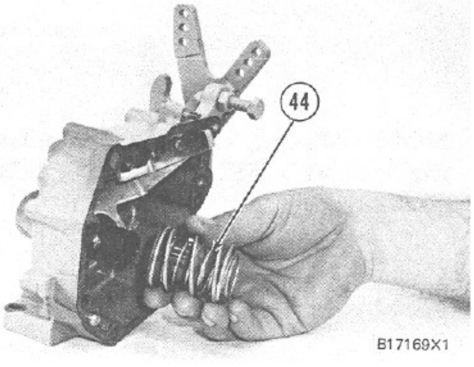
25. Install the bolts that hold the lever to the shaft assembly.

26. Install springs (42) and (43) on seat (41).

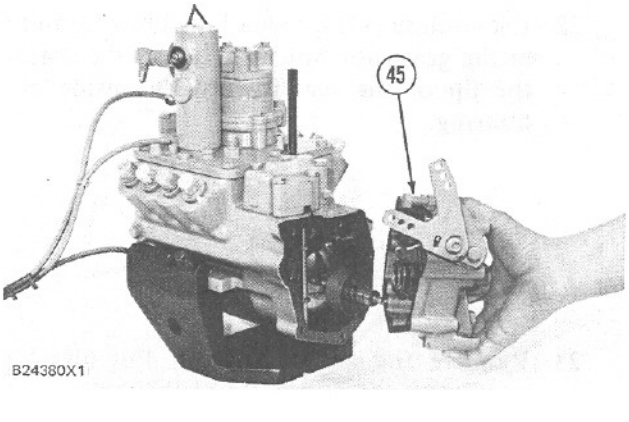


NOTICE

Both springs must make full contact on the seat before they are installed in the governor housing assembly. If the springs do not make full contact on the seat, high idle speed will not be correct and low idle governor surge can be the result. Low idle setting without stability can also be the result.



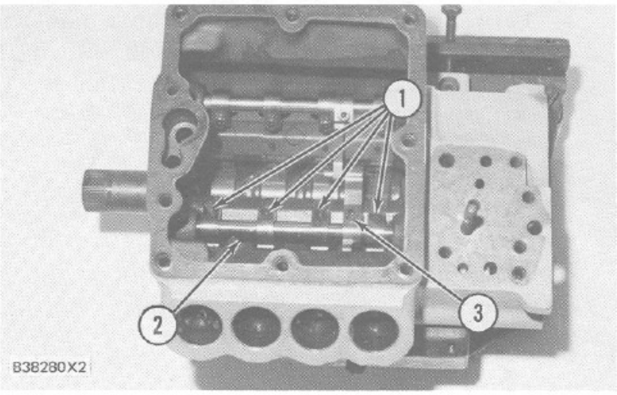
27. Install seat assembly (44) in the governor housing.



28. Put the gasket in position. Install governor housing assembly (45) on the fuel pump housing.
   end by:
   a) make an adjustment of the fuel system setting (See FUEL SYSTEM in TESTING AND ADJUSTING)
   b) install fuel injection pump housing and governor
   c) install inlet manifold

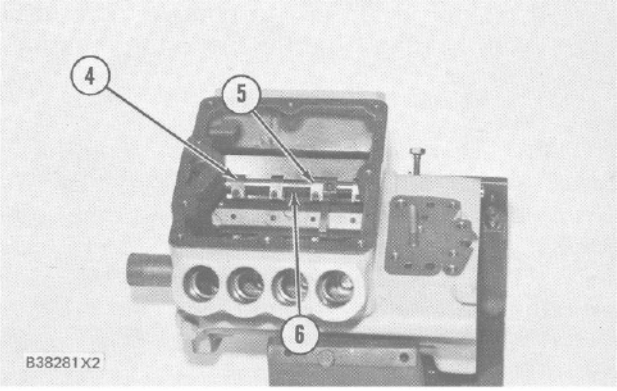
FUEL INJECTION PUMP HOUSING

DISASSEMBLE FUEL INJECTION PUMP HOUSING 1253-15

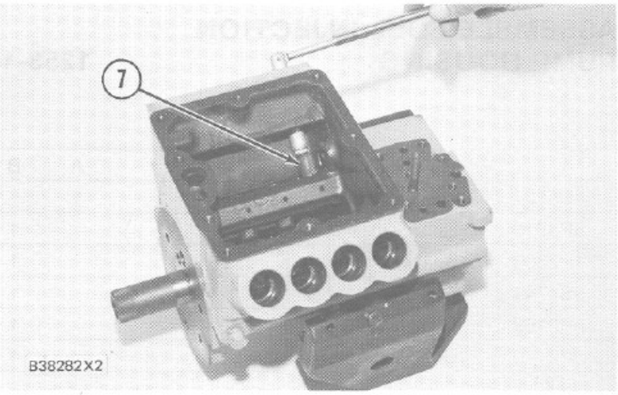


	Tools Needed	A
1P510	Driver Group	1

start by:
a) remove fuel injection pumps
b) separation of governor from fuel injection pump housing
c) remove fuel transfer pump

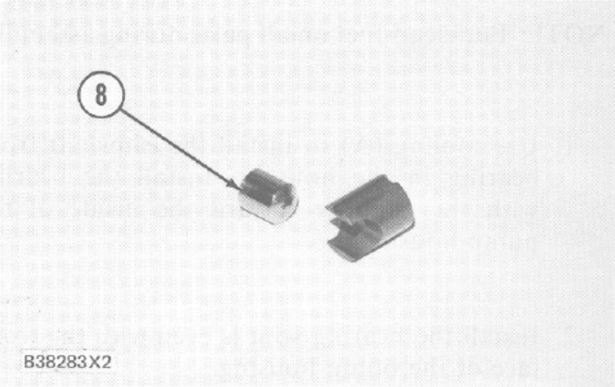


1. Loosen screws (1) in the levers and remove screw (3) in the crossover lever. Slide shaft assembly (2) out of the housing.



2. Loosen screws in levers (4) and remove the screw in crossover lever (5). Slide shaft (6) out of the housing.

NOTE: Put identification on lifters (7) and rollers (8) for installation in their respective bores in the housing.

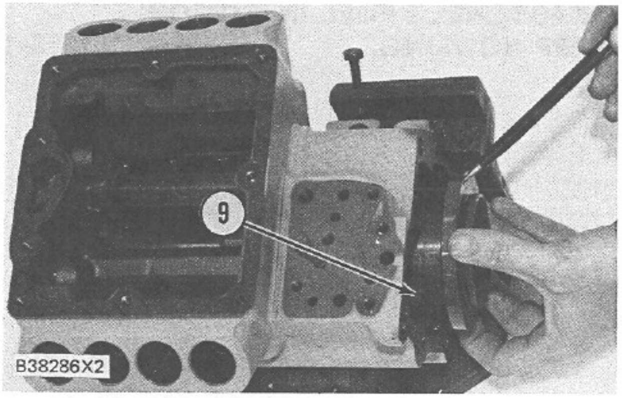


3. Use a magnet to remove eight lifter assemblies (7).

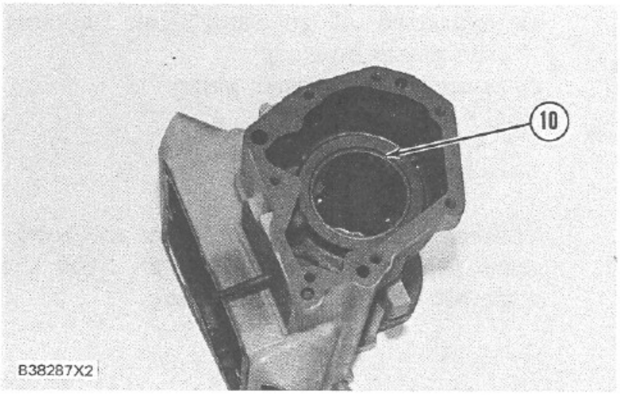
4. Remove roller (8) from each lifter assembly.

FUEL INJECTION PUMP HOUSING

5. Turn the camshaft so the groove (slot) for the timing pin is in the position shown and carefully remove camshaft (9). Remove the thrust washer from the housing.



6. Remove camshaft rear bearing (10) from the fuel pump housing. Be careful not to damage the bearing bore in the housing.

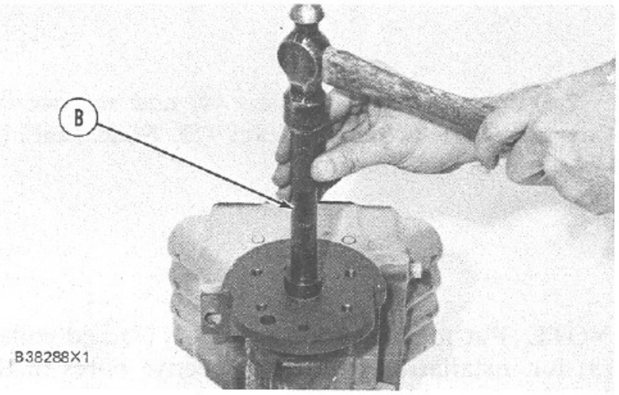


7. Use tool group (A) to remove the camshaft front bearing from the fuel pump housing.

NOTE: Earlier fuel pump housings do not have a thrust washer for the camshaft. The 6V4068 Tool Group can be used to machine the housing so the 9N5822 Thrust Washer can be used. See SPECIAL INSTRUCTION Form No. SMHS7897 for the procedure to machine the housing.

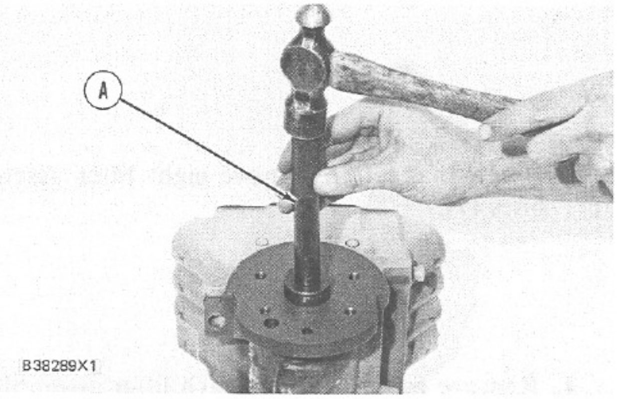
ASSEMBLE FUEL INJECTION PUMP HOUSING 1253-16

	Tools Needed	A	B
1P510	Driver Group	1	
5P3516	Reaming Tool Group		1
1P2363	Swivel Joint		1
9S1744	Adapter		1
5P2169	Master Gauge		1
5P2170	Dial Gauge Group		1



NOTE: Put clean fuel on all parts during assembly.

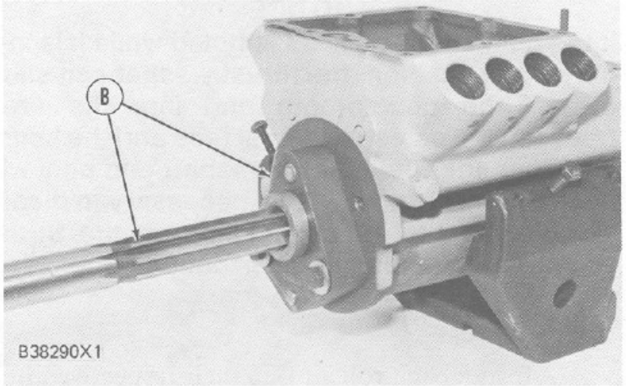
1. Use tooling (A) to install the camshaft front bearing in the housing. Install the bearing with the chamfer toward the inside of the pump housing.



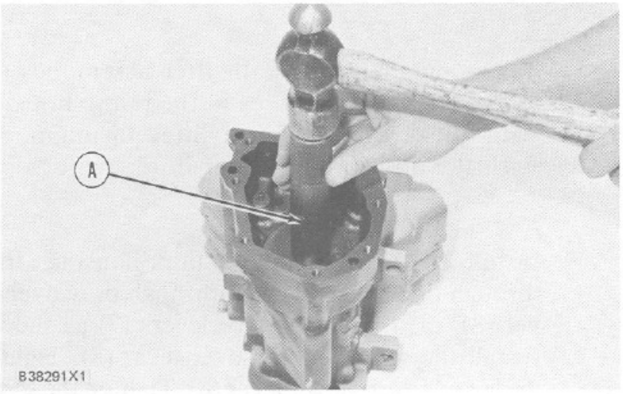
2. Install the bearing so it is even with the front face of the pump housing.

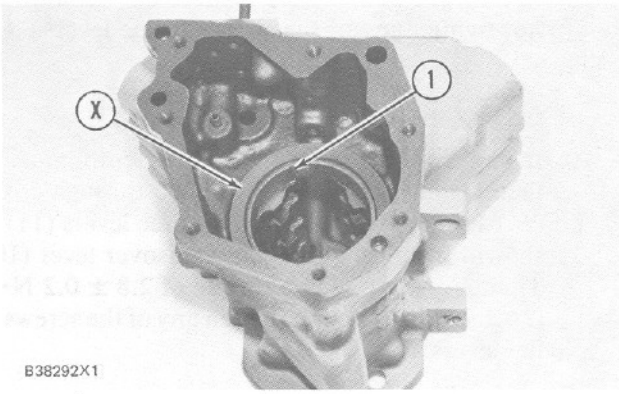
FUEL INJECTION PUMP HOUSING

3. Use tooling (B) to machine the bore in the camshaft front bearing to the correct size. See SPECIAL INSTRUCTION Form No. SMH6735 for the procedure to machine the new camshaft front bearing. The bore in the bearing must be 25.413 ± 0.013 mm (1.0005 ± .0005 in.).

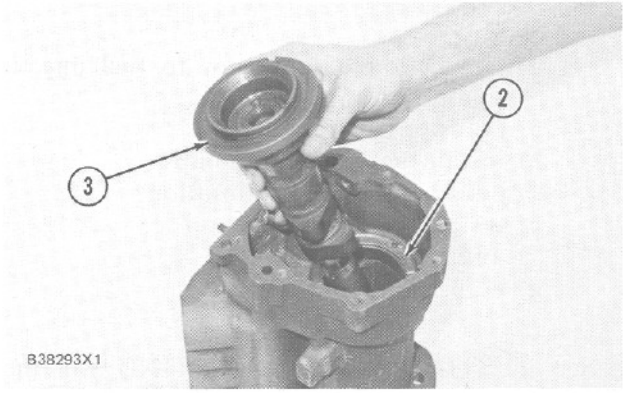


4. Use tooling (A) to install the camshaft rear bearing in the housing. Install the bearing so groove (1) in the bearing is in the position shown. On earlier pump housings without a thrust washer install the bearing into the bore so the outer face of the bearing is 0.114 ± 0.025 mm (.0045 ± .0010 in.) below face (X) on the housing. On later pump housings with a thrust washer install the bearing into the bore so the outer face of the bearing is 0.43 ± 0.13 mm (.017 ± .005 in.) below the counterbore for the thrust washer.





5. Install thrust washer (2) in the housing with the ear on the thrust washer in the hole in the pump housing so the thrust washer will not turn.



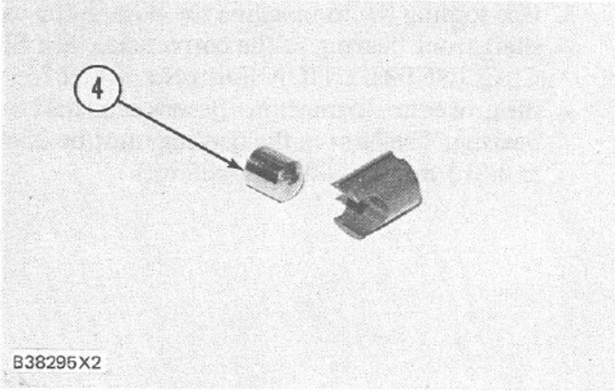
6. With the pump housing in a vertical position as shown, carefully install camshaft (3). To make sure that the thrust washer will be kept in its correct installation location, keep the pump housing in a vertical position and install the fuel transfer pump and camshaft sleeve. See FUEL TRANSFER PUMP INSTALLATION for the procedure to install the fuel transfer pump and camshaft sleeve.

FUEL INJECTION PUMP HOUSING

NOTICE

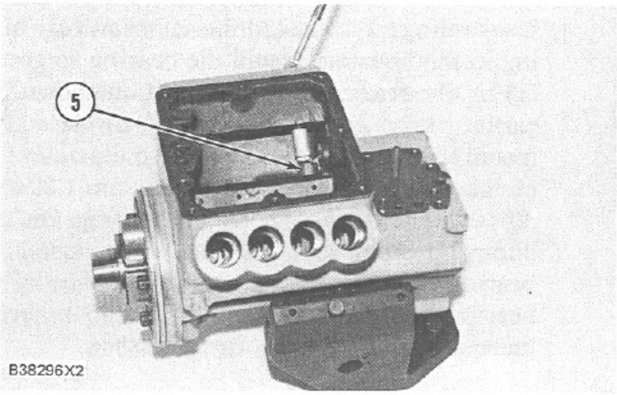
If the pump housing is assembled while it is in a horizontal position, the thrust washer can slide out of the counterbore and into the area between the camshaft thrust face and the housing. Then the fuel pump camshaft end play will not be correct and it will be necessary to disassemble the fuel pump housing so the thrust washer can be installed correctly.

7. Install each roller (4) in their respective lifters.



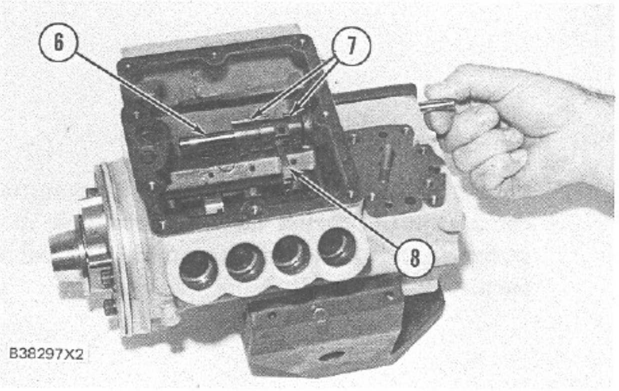
B38295X2

8. Use a magnet to install lifter assemblies (5) in their respective bores in the pump housing with the groove in each lifter in alignment with the dowel in the lifter bore.



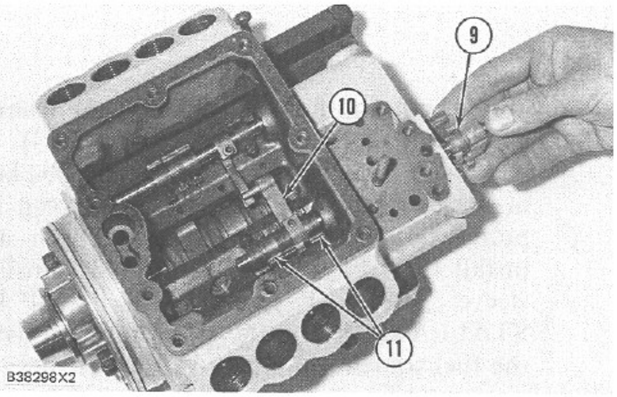
B38296X2

9. Install shaft (6) in the pump housing, then through one lever (7), then through crossover lever (8), then through three levers (7) as shown. Install the screw in crossover lever (8). Tighten the screw in crossover lever (8). Tighten the screw to a torque of 2.8 ± 0.2 N•m (24 ± 2 lb.in.). Do not tighten any of the screws in the levers.



B38297X2

10. Install shaft assembly (9) in the pump housing, then through one lever (11), then through crossover lever (10), then through three levers (11) as shown. Install the screw in crossover lever (10). Tighten the screw to a torque of 2.8 ± 0.2 N•m (24 ± 2 lb.in.). Do not tighten any of the screws in the levers.



B38298X2

end by:

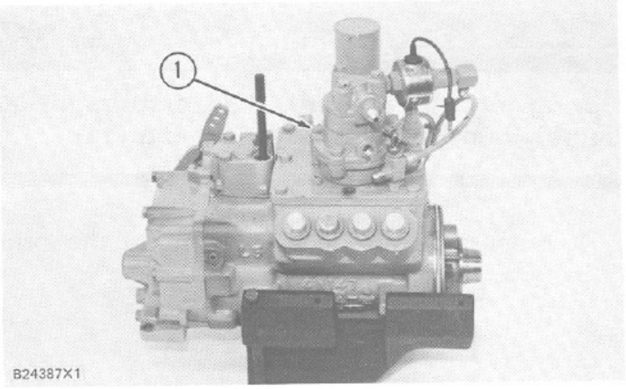
a) connection of governor to fuel injection pump housing
b) adjust crossover levers*
c) install fuel injection pumps
d) adjust fuel pump calibration*
e) install fuel transfer pump
f) adjust fuel setting*
g) adjust high and low idle*

*See TESTING AND ADJUSTING for these procedures.

FUEL RATIO CONTROL

REMOVE FUEL RATIO CONTROL 1278–11

1. Remove two bolts (1).
2. Remove fuel ratio control and gasket.

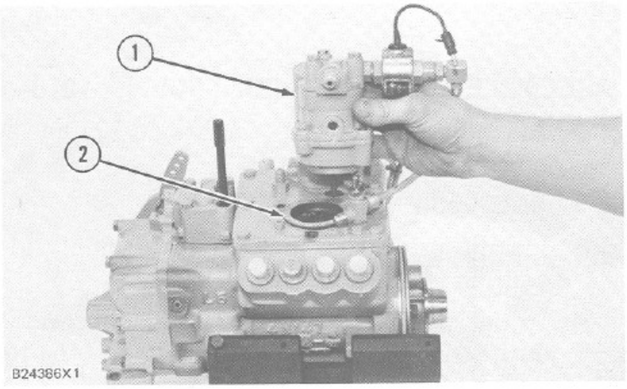


INSTALL FUEL RATIO CONTROL 1278–12

1. Put gasket (2) in position.

NOTE: Make an alignment with the lever in the shut-off housing with the plunger in the fuel ratio control. control.

2. Install fuel ratio control (1) and the bolts that hold it.

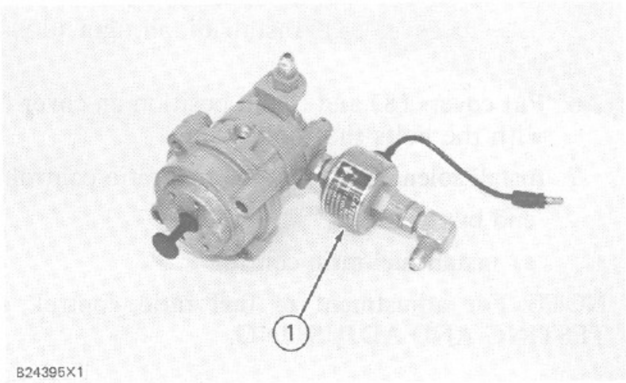


DISASSEMBLE FUEL RATIO CONTROL 1278–15

start by:

a) remove fuel ratio control

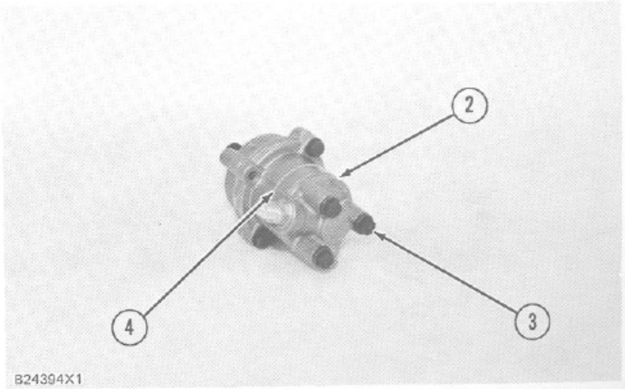
1. Remove solenoid (1) from the fuel ratio control.



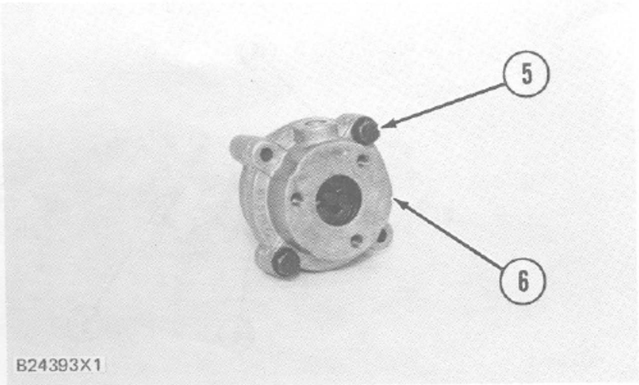
2. Remove bolts (3) and covers (2) and (4). Remove diaphragm (11) and piston (17). Remove gasket (16) from cover (4).

⚠ WARNING

Spring force is present. Slowly loosen the two bolts to release the force.



3. Remove two bolts (5), cover (6) and spring (15).

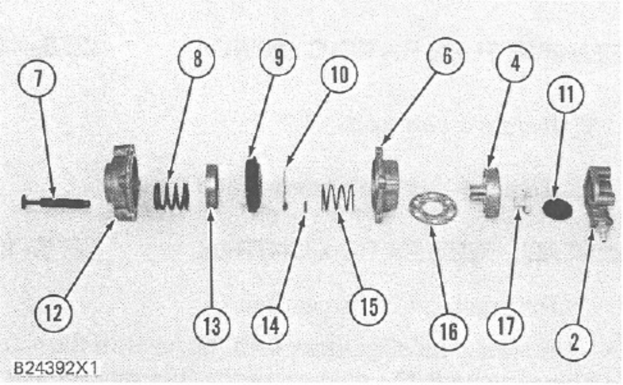


FUEL RATIO CONTROL

⚠ WARNING

Spring force is present. Hold diaphragm assembly in position and remove pin (14).

4. Remove pin (14) and slowly release the spring force.
5. Remove spring (8) and bolt(7) from housing (12).
6. Remove washer (10) and diaphragm (9) from retainer (13).



B24392X1

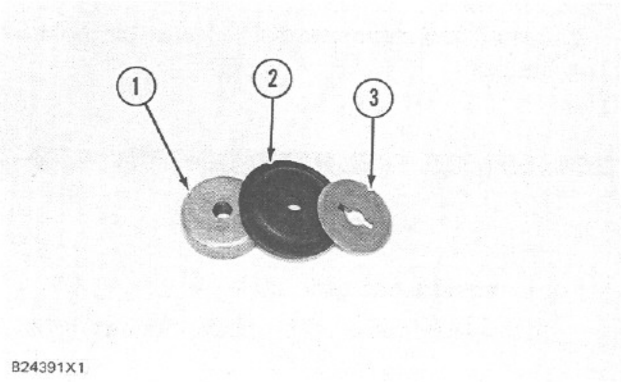
ASSEMBLE FUEL RATIO CONTROL 1278–15

1. Assemble washer (3), diaphragm (2) and retainer (1).
2. Install bolt (4) in housing (10).
3. Install spring (5), diaphragm assembly (11) and pin (6) in housing (10).
4. Install spring (22) in cover (7). Install cover (7) on housing (10) with the two bolts (16) that hold it.
5. Install gasket (13) on cover (8). Install piston (14) to cover (8). Install diaphragm (15) in cover (9).
6. Put covers (8) and (9) in position on cover (7) with the bolts that hold them.
7. Install solenoid (17) on the fuel ratio control.

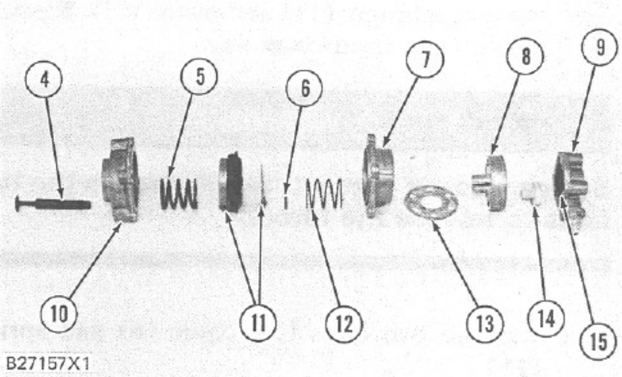
end by:

a) install fuel ratio control

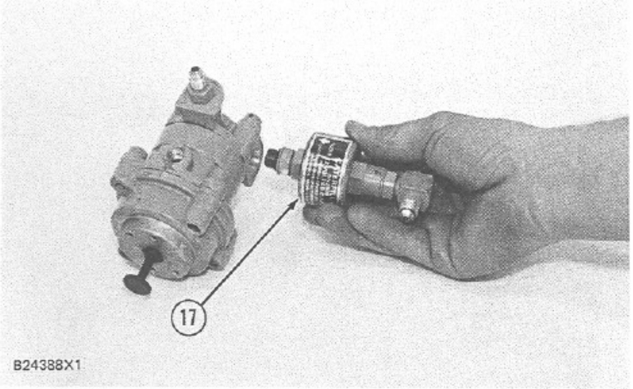
NOTE: For adjustment of fuel ratio control, see TESTING AND ADJUSTING.



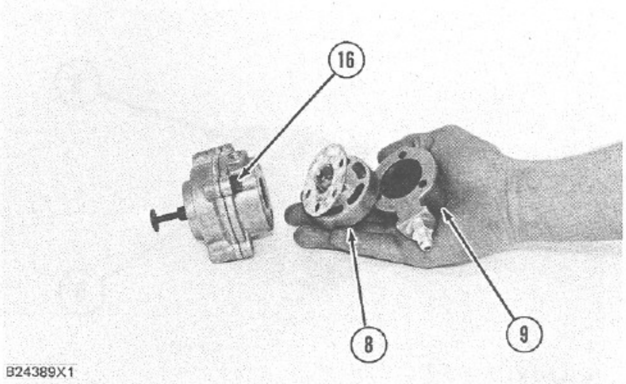
B24391X1



B27157X1



B24388X1



B24389X1

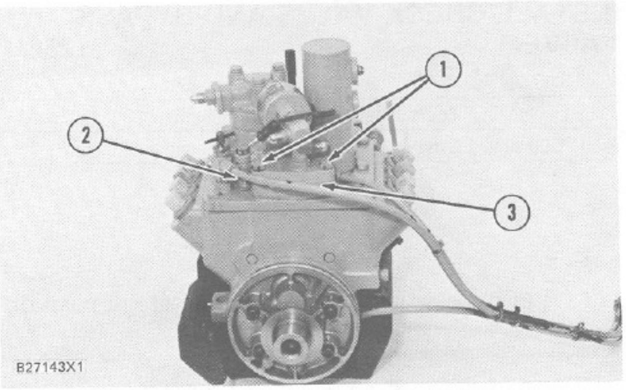
CHECK VALVE AND BYPASS VALVE

REMOVE CHECK VALVE AND BYPASS VALVE 1256-11

NOTICE

Before any service work is done on the fuel system, the outer surface of the injection pump housing must be clean.

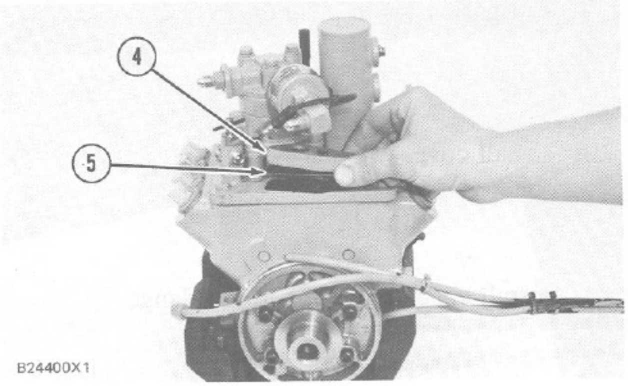
NOTE: Illustrations show fuel injection pump housing and governor removed from engine. Service work can be done with it installed on engine.



B27143X1

1. Remove three bleed lines (2).

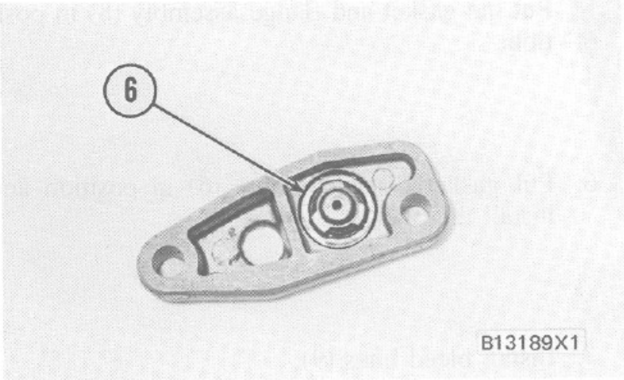
2. Remove bolts (1), flange (3) and the gasket.



B24400X1

3. Remove flange assembly (4) and gasket (5).

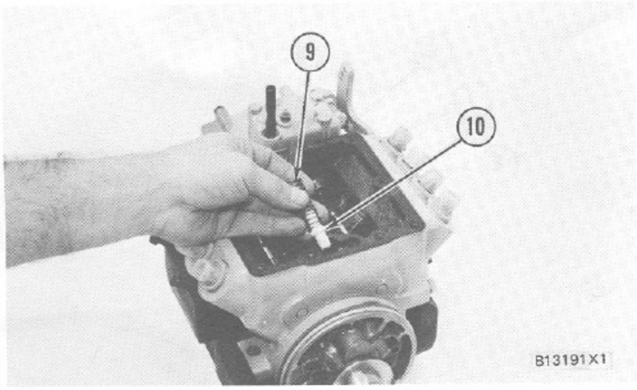
4. Remove check valve (6) from the flange assembly.



B13189X1

5. Remove bolts (7) and cover (8).

6. Remove spring (9) and bypass valve (10).



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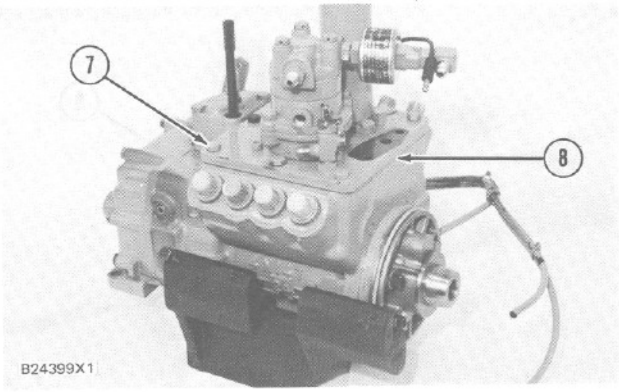


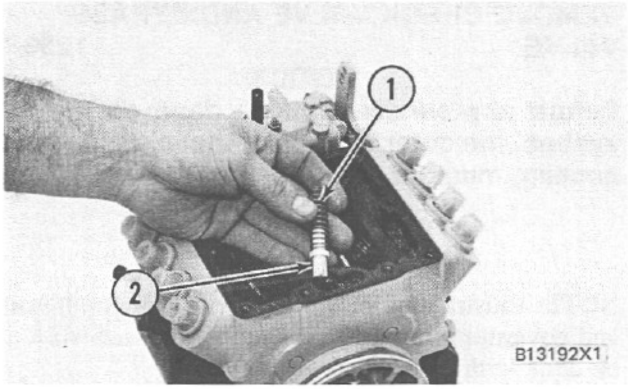
B24399X1

CHECK VALVE AND BYPASS VALVE

INSTALL CHECK VALVE AND BYPASS VALVE 1256-12

	Tools Needed	A
1P500	Driver Group	1

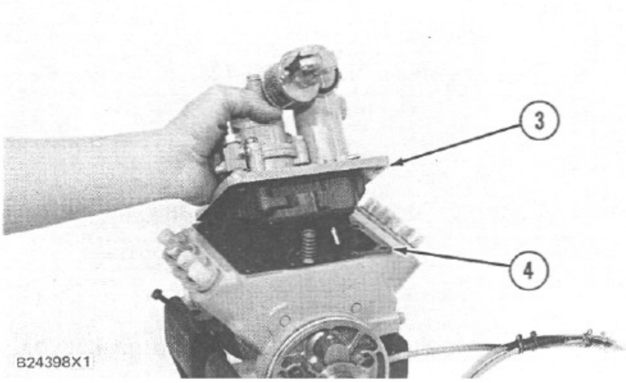
1. Put bypass valve (2) and spring (1) in position.



B13192X1

2. Put gasket (4) in position.

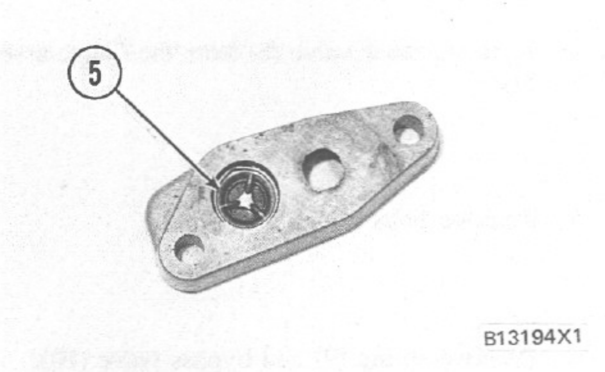
3. Install cover (3) and the bolts.



B24398X1

4. Install check valve (5) in the flange.

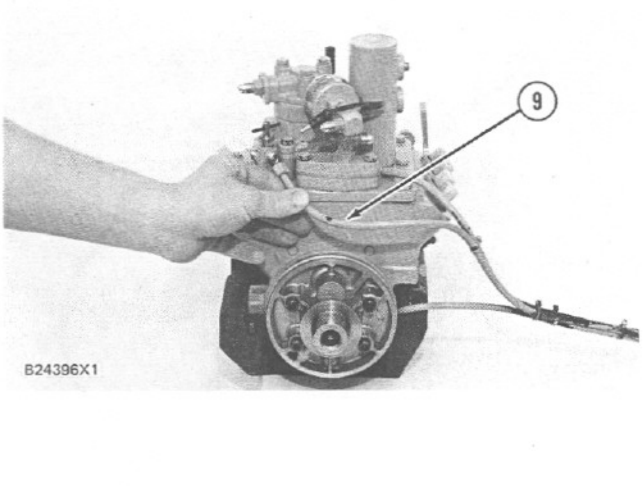
5. Put the gasket and flange assembly (8) in position.



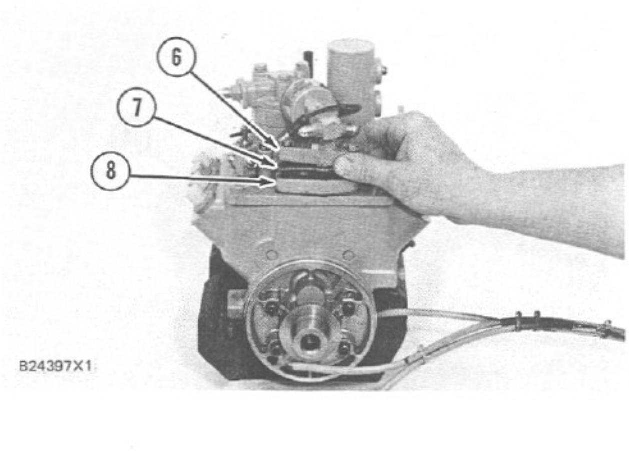
B13194X1

6. Put gasket (7) and flange (6) in position and install the bolts.

7. Install bleed lines (9).



B24396X1



B24397X1

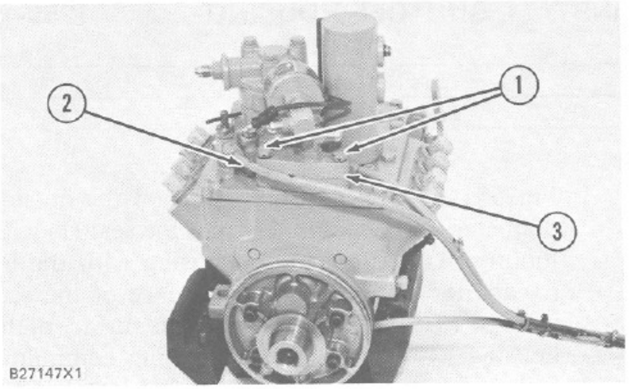
SHUTOFF HOUSING

REMOVE SHUTOFF HOUSING 1259-11

NOTICE

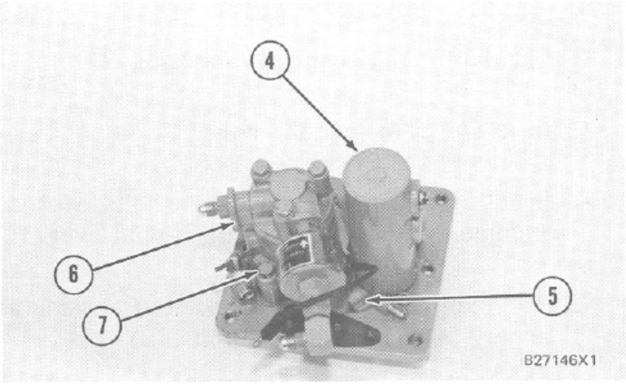
Before any service work is done on the fuel system, the outer surface of the injection pump housing must be clean.

NOTE: Illustrations show fuel injection pump housing and governor removed from engine. Service work can be done with it installed on engine.



1. Remove air bleed lines (2).

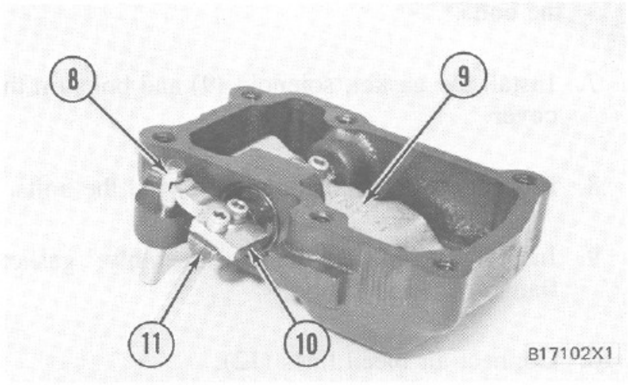
2. Remove bolts (1), flange (3), the flange assembly and the gaskets.



3. Remove the bolts and the cover.

4. Remove bolts (5), solenoid (4) and the gasket.

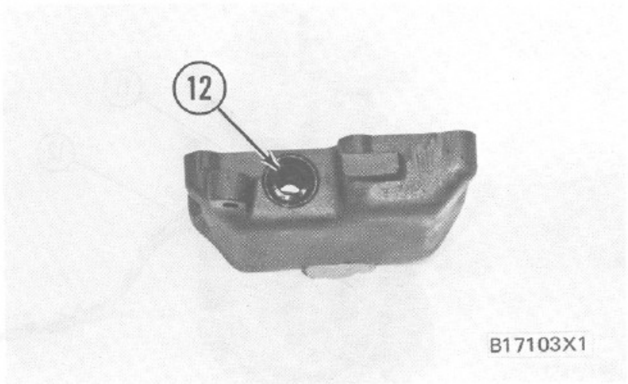
5. Remove two bolts (7) and fuel ratio control (6).



6. Remove the shutoff housing from the cover.

7. Remove the bolts, lever (10) and shaft (8).

8. Remove the bolts, lever (9) and shaft (11).



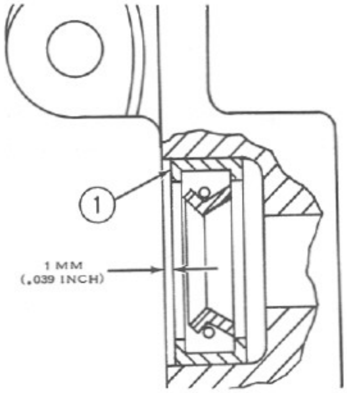
9. Remove seal (12) from the shutoff housing.

SHUTOFF HOUSING

INSTALL SHUTOFF HOUSING 1259-12

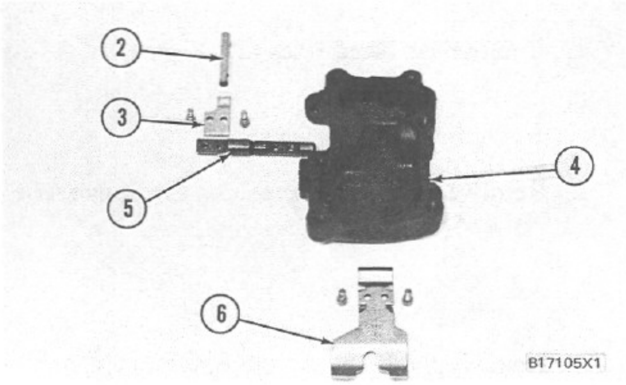
	Tools Needed	A
1P500	Driver Group	1

1. Put 5S1454 Sealing Compound on the outside diameter of the seal and install the seal (1) with tooling (A) in the shutoff housing with the lip toward the outside. The outer face of the seal must be 1.0 mm (.039 in.) below the surface of the housing. Remove the extra sealing compound from the housing and the seal after installation.



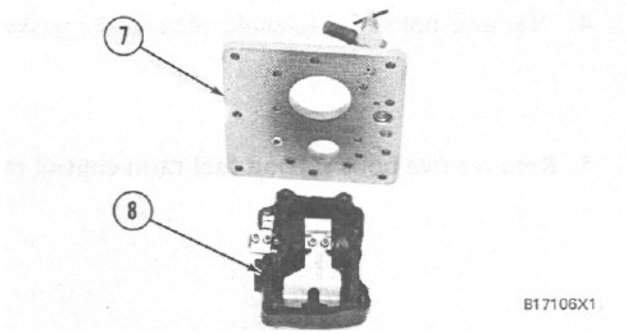
80821X1

2. Put shaft (5) in position in housing (4).
3. Install lever (6) and the bolts.
4. Install shaft (2), lever (3) and the bolts. Make an alignment of the notch in shaft (2) with lever (3).



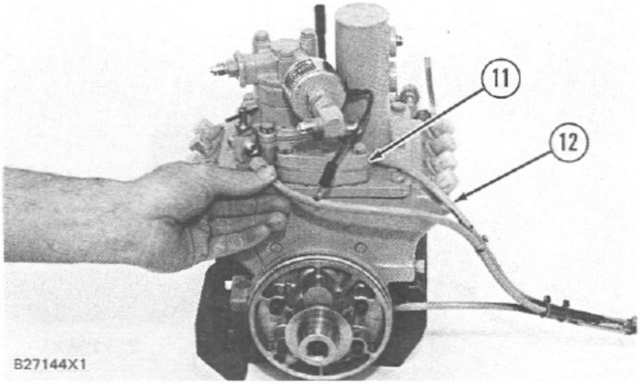
B17105X1

5. Put cover (7) in position on shutoff housing assembly (8) and install the bolts.

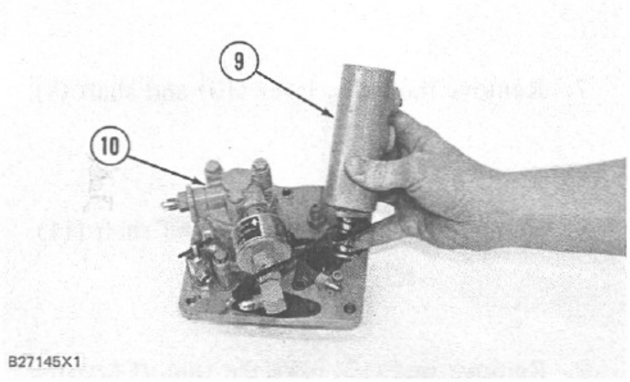


B17106X1

6. Put fuel ratio control (10) in position and install the bolts.
7. Install the gasket, solenoid (9) and bolts on the cover.
8. Put the cover in position and install the bolts.
9. Install the gasket, flange assembly, gasket, flange (11) and the bolts.
10. Connect air bleed lines (12).



B27144X1



B27145X1

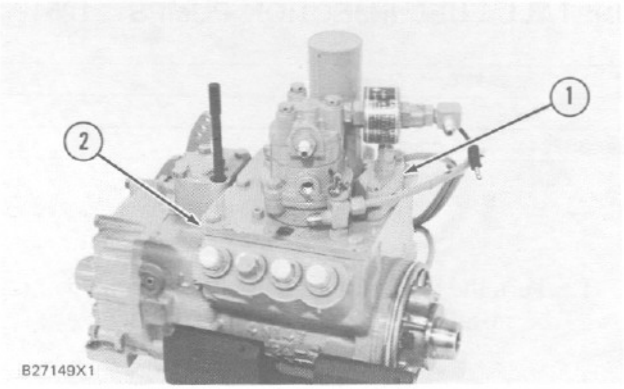
FUEL INJECTION PUMPS

REMOVE FUEL INJECTION PUMPS 1251-11

	Tools Needed	A
8S2243	Wrench	1
8S2244	Extractor	1

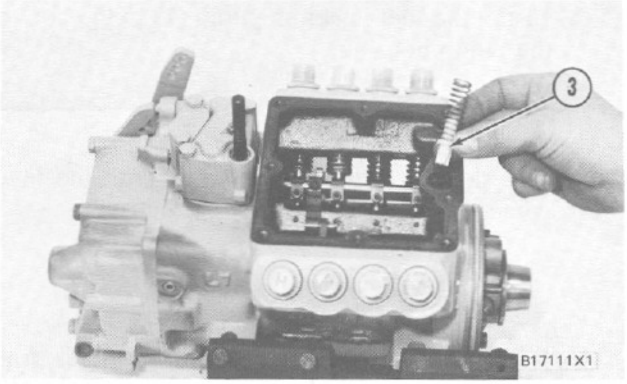
NOTICE

Before any service work is done on the fuel system, the outer surface of the injection pump housing must be clean.

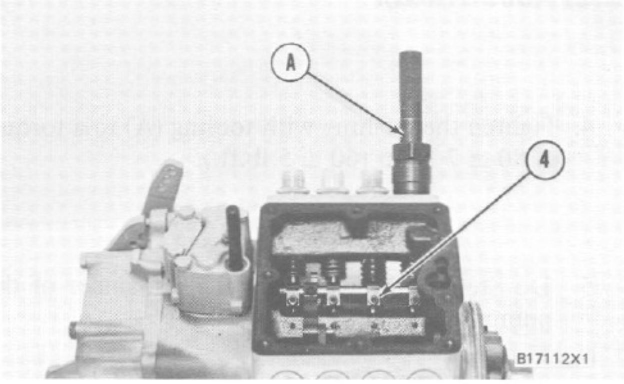


NOTE: The fuel injection pump housing and governor has been removed from the engine for illustration purposes.

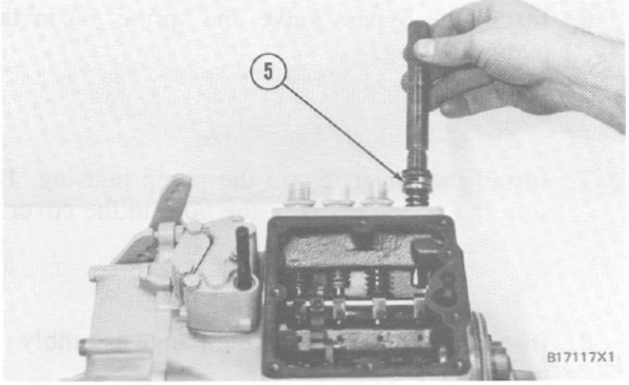
1. Remove flange (1) and the flange assembly from the cover.
2. Remove cover (2) from the pump housing.



3. Remove the bypass valve (3) and springs from the pump housing.
4. Install tooling (A) on the fuel injection pump and loosen the bushing from the pump housing.



NOTE: Do not loosen screws (4) that hold the levers to the shaft when the pumps are removed or installed. If the levers are moved, fuel pump calibration will be changed.

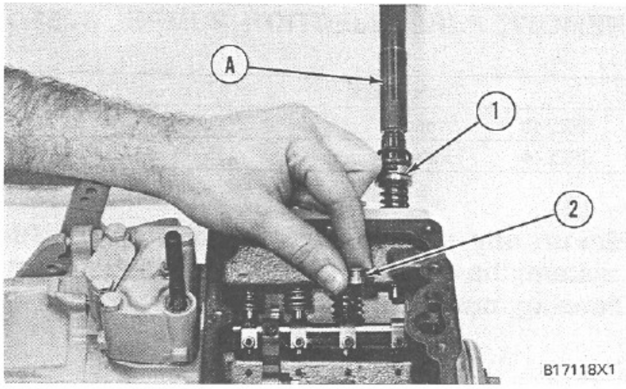


5. Remove the fuel injection pump (5) from the pump housing. The sleeve on the plunger will slide off the lever as the pump is removed.
6. Do Steps 4 and 5 for the remainder of the pumps.

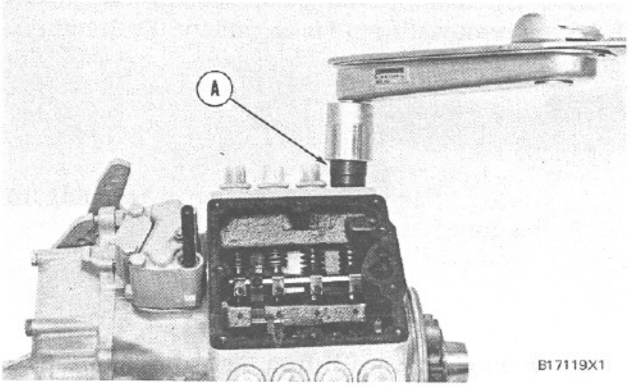
FUEL INJECTION PUMPS

INSTALL FUEL INJECTION PUMPS 1251-12

	Tools Needed	A
8S2243	Wrench	1
8S2244	Extractor	1



1. Turn the camshaft until the lifter for the pump to be installed is at its lowest position.

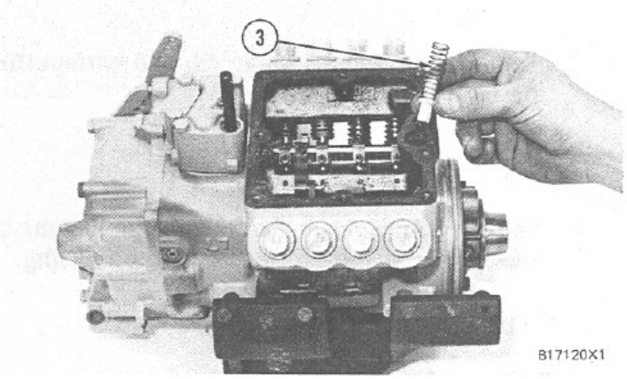


2. Install the fuel injection pump (1) in the bore of the pump housing.

3. The sleeve (2) will be engaged with the lever when the pump is installed correctly.

NOTICE

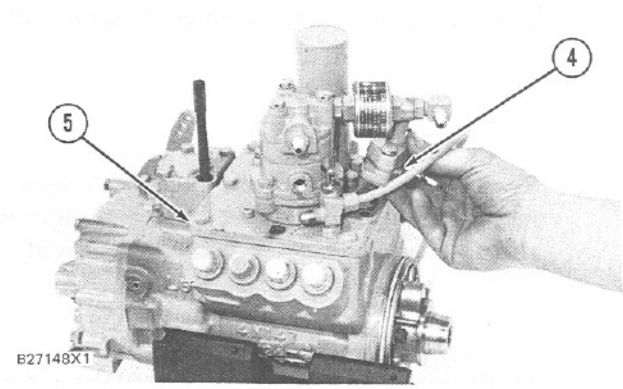
If the levers have been moved on the shaft, fuel pump calibration must be made. (See TESTING AND ADJUSTING).



4. Tighten the bushing with tooling (A) to a torque of 80 ± 7 N•m (60 ± 5 lb.ft.).

5. Do Steps 1 through 4 for the remainder of the pumps.

6. Install the bypass valve and spring (3) in the pump housing.

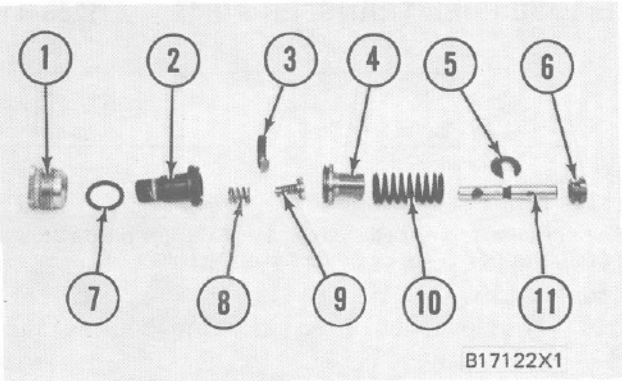


7. Install the cover (5) on the pump housing. Be sure the spring (3) is in the bore in the cover.

8. Install the flange (4) and the flange assembly on the cover.

FUEL INJECTION PUMPS

DISASSEMBLE FUEL INJECTION PUMPS 1251-15



1. Remove bushing (1) and O-ring seal (7) from bonnet (2).

2. Remove ring (3) from the bonnet and barrel (4).

3. Remove check valve assembly (9) and spring (8) from the bonnet.

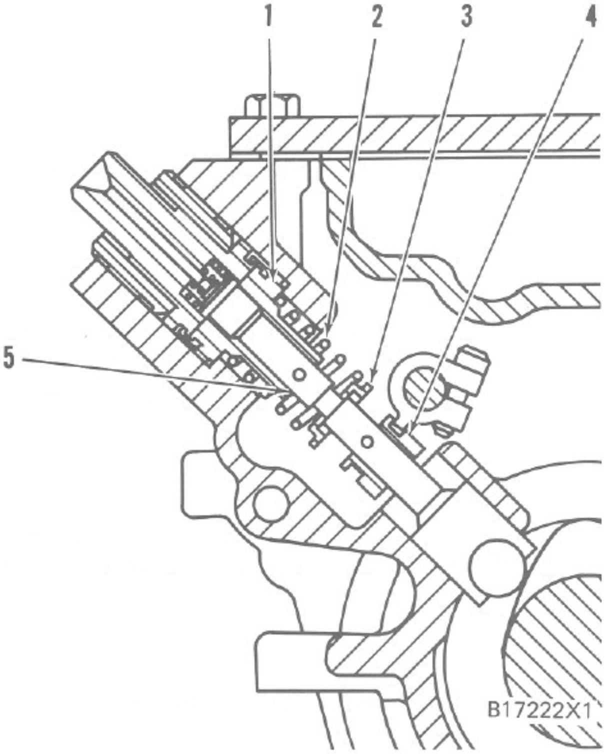
4. Remove spring (10) and retainer washer (5).

NOTICE

Keep the plunger and sleeve with their respective barrel for installation. Do not use plungers, sleeves and barrels with other plungers, sleeves and barrels.

5. Remove plunger (11) and sleeve (6).

ASSEMBLE FUEL INJECTION PUMPS 1251-16



1. Install the sleeve (4), plunger (5), spring (2) and washer (3) on barrel (1).

NOTICE

Be sure the sleeve and plunger are installed in their original barrel and the large hole in the plunger is up. The sleeve must be installed with the thin flange up.

2. Install the check valve assembly and spring in the bonnet. Connect the barrel and bonnet with the ring. Install the seal and bushing on the bonnet.

end by:

a) install fuel injection pumps

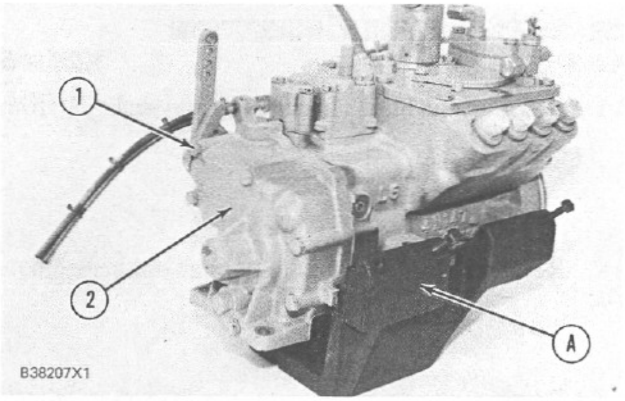
FUEL TRANSFER PUMP

REMOVE FUEL TRANSFER PUMP 1256-11

	Tools Needed	A	B	C
2P8315	Bracket Assembly	1		
3P1544	Timing Pin		1	
*2H3740	Bolt (¾"-16 NF x 1 ¼ in.)			1

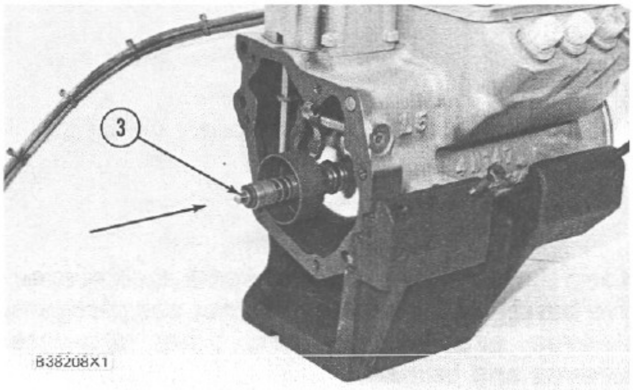
*Bolt is modified to prevent thread damage. To do this, grind a 2 to 4 mm (.079 to .157 in.) bevel on the end of the bolt.

start by:
a) remove fuel injection pump housing and governor

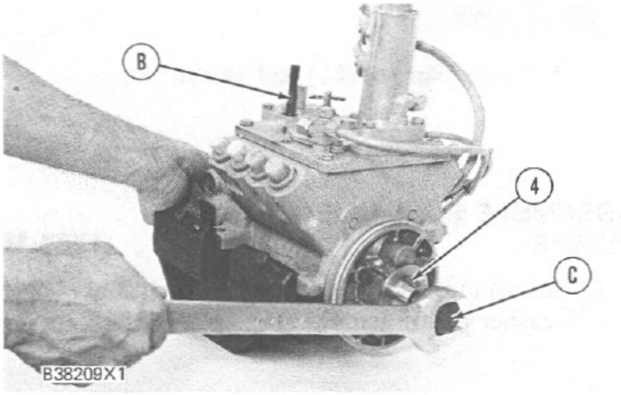


1. Install the fuel injection pump housing on tool (A).

2. Remove seven bolts (1) and governor housing (2).

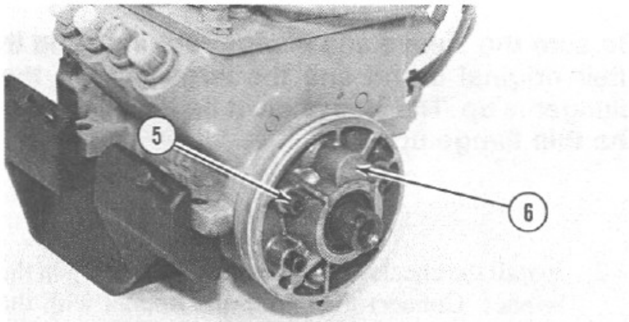


NOTE: Later fuel injection pump housings have a thrust washer for the fuel injection pump camshaft. The thrust washer is behind the flange for the flyweights on the camshaft. To hold the thrust washer in place governor shaft (3) and the camshaft must be held in toward the fuel transfer pump any time sleeve (4) is removed.



3. Remove the plug from the cover and install tool (B) in the hole as shown. Turn the injection pump camshaft until tool (B) can be pushed into the groove (slot) in the camshaft.

NOTE: Any time the drive sleeve is removed from the camshaft a new one must be installed. The camshaft has serrations (splines) that cut grooves into the drive sleeve when it is installed to give a positive drive connection. If a formerly used drive sleeve is installed again it can slip (slide around) on the camshaft.

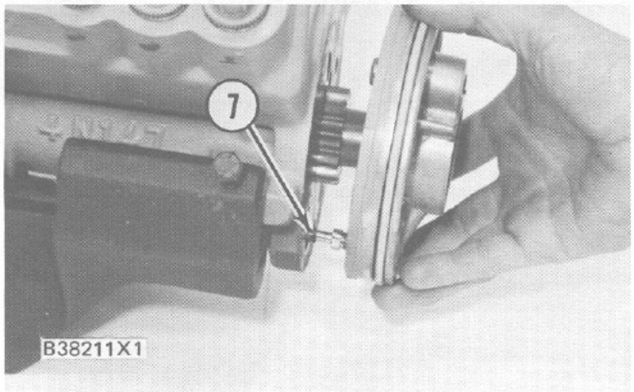


4. Install tool (C) in the threads of sleeve (4). Tighten the bolt until the sleeve can be removed.

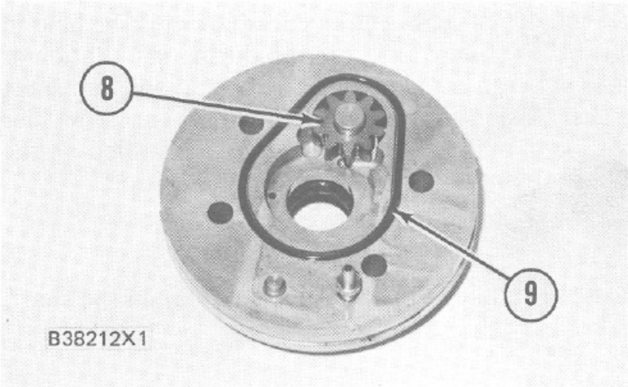
5. Remove four bolts (5) and fuel transfer pump body (6) from the housing.

FUEL TRANSFER PUMP

6. Disconnect drain line (7) from the fitting on the back of fuel transfer pump body.



7. Remove gear (8) and O-ring seal (9) from the pump body.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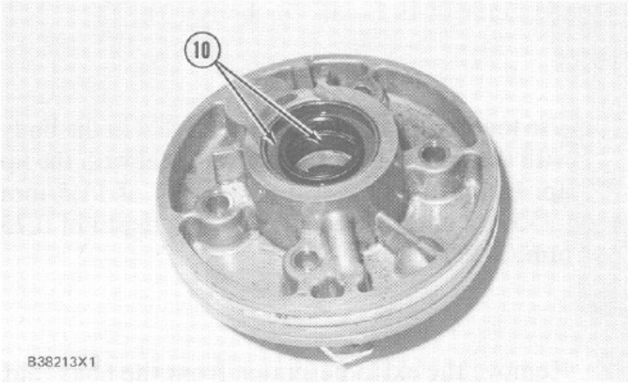
B38212X1

8. Remove seals (10) from the pump body.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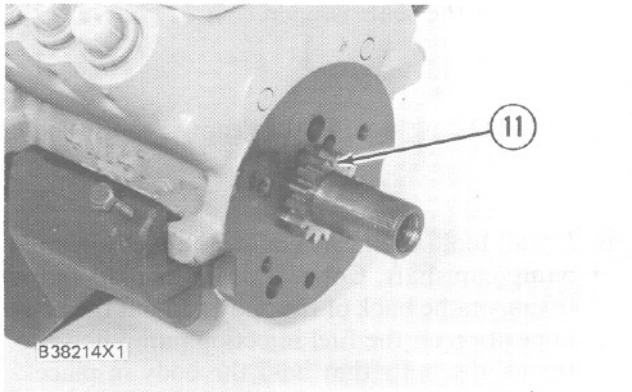
B38213X1

9. Remove drive gear (11) and the key from the camshaft.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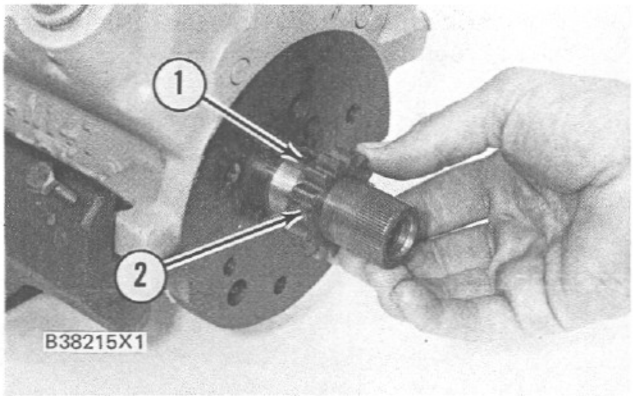
B38214X1

FUEL TRANSFER PUMP

INSTALL FUEL TRANSFER PUMP 1256-12

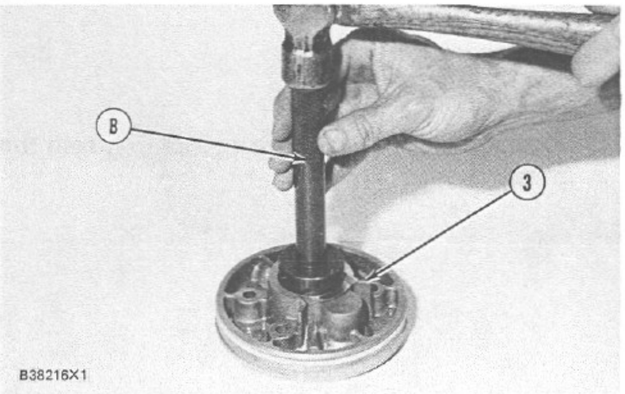
	Tools Needed	A	B	C	D	E
2P8315	Bracket Assembly	1				
1P510	Driver Group		1			
6V3071	Seal Guide			1		
S1603	Bolt (½"-20 NF x 1 ½ in.)				1	
4B4280	Washer				1	
3P1544	Timing Pin					1

NOTE: The fuel injection camshaft must be held in toward the fuel transfer pump during installation of the fuel transfer pump parts to hold the camshaft thrust washer in its counterbore. The thrust washer will be damaged when the sleeve is installed on the camshaft if it is not in the correct position.



B38215X1

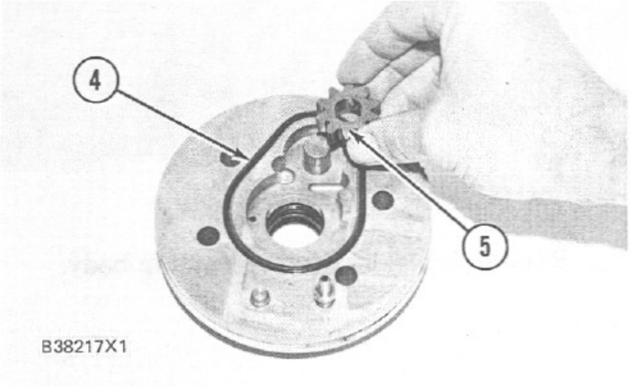
1. Install key (1) and drive gear (2) on the shaft.



B38216X1

2. Put No. 3 Aviation Permatex on the outside diameter of the seals for body (3).

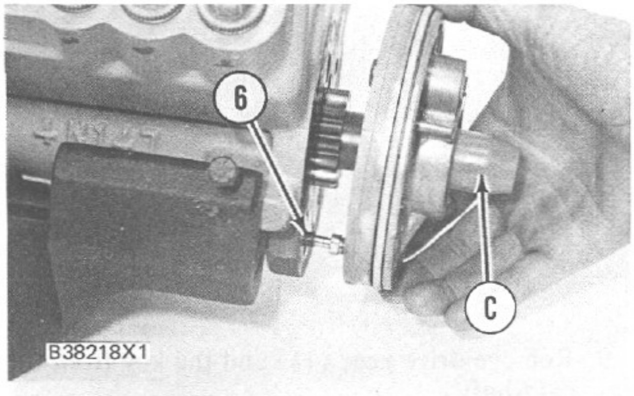
3. Use tooling (B) to install the first seal in the body with the lip down and the second seal with the lip up. Install the first seal to a depth of 11.5 mm (.453 in.) and the second seal to a depth of 0.75 mm (.030 in.).



B38217X1

4. Remove the extra permatex from the body and seals after installation. Be sure the drain hole between the seals is open.

5. Install O-ring seal (4) and gear (5) on the body.

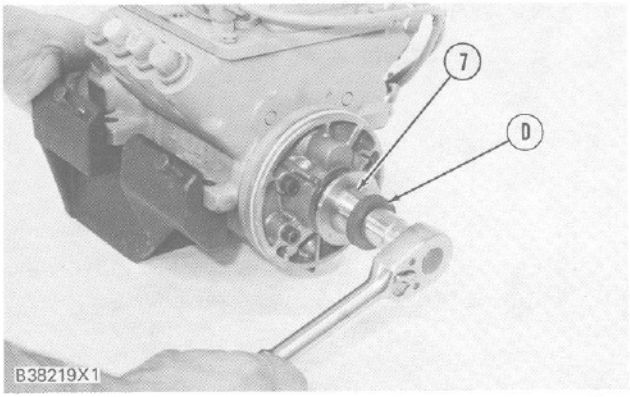


B38218X1

6. Install tool (C) in the end of the fuel injection pump camshaft. Connect drain line (6) to the fitting on the back of the body and put the body in position on the fuel injection pump housing. Install the bolts that hold the body in place.

FUEL TRANSFER PUMP

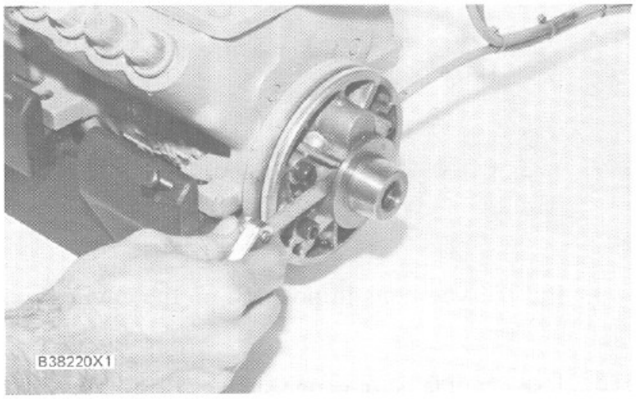
7. Install tool (E) in the camshaft so it will not turn.



8. Put a new sleeve (7) on the camshaft.

NOTE: A new drive sleeve must be installed because a used drive sleeve can slip (slide around) on the camshaft.

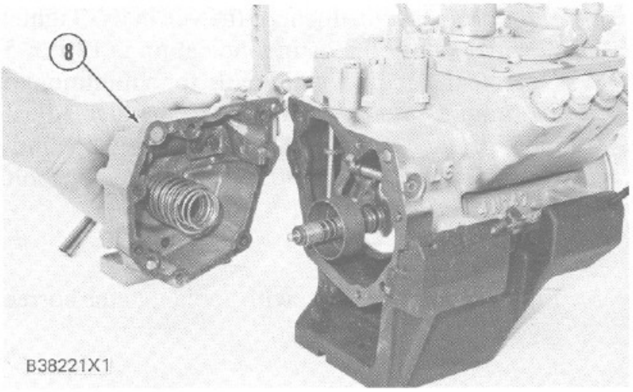
9. Tighten the sleeve into position on the shaft with the 4B4280 Washer of tooling (D) approximately 6.4 mm (.25 in.). Tighten the sleeve the remainder of the way with the 9N5022 Washer until the sleeve is at bottom. This is the washer which is on the tachometer drive shaft.



NOTICE

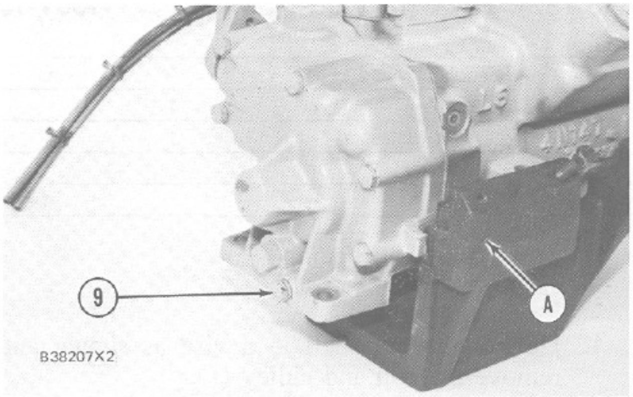
Do not hit the sleeve to install. Damage to the governor will be the result.

10. Use a feeler gauge to check the end play of the camshaft after the sleeve is installed. The end play of the camshaft must be 0.58 ± 0.46 mm (.023 ± .018 in.).



11. Be sure the governor springs and gasket are in position on governor housing (8). Install the governor housing on the fuel injection pump housing.

12. Be sure bolt (9) has the washer and O-ring seal on it when installed.

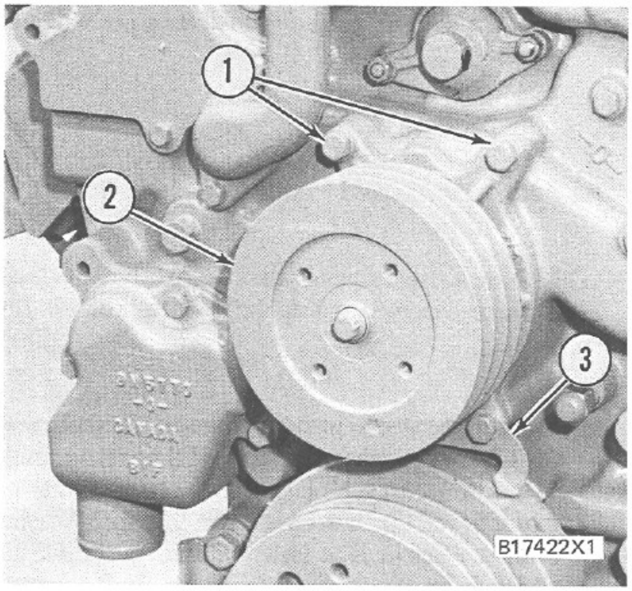


13. Remove the fuel injection pump housing from tool (A).
    end by:
    a) install fuel injection pump housing and governor

WATER PUMP

REMOVE WATER PUMP 1361-11

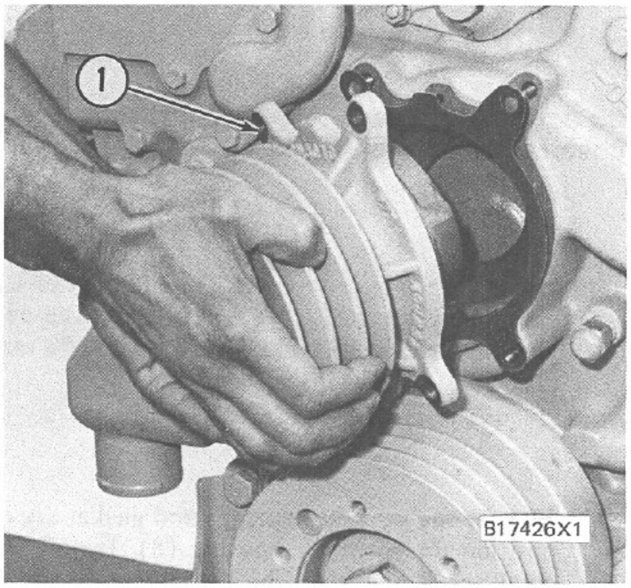
1. Drain the coolant from the cooling system.
2. Remove the vee belts from the front of the engine.
3. Remove bolts (1) and pointer (3). Remove water pump (2) from the timing gear cover.



INSTALL WATER PUMP

1361-12

1. Put the gasket and water pump (1) in position in the timing gear cover.
2. Install the pointer and bolts to hold the water pump.
3. Put the vee belts in position on the engine.
4. Use a belt tension gauge such as Borroughs Tool Company Part No. BT-33-72C or an equivalent and make an adjustment of the vee belts. Tighten new belts until the gauge indication is 120 ± 5. Operate the engine at high idle for a minimum of 30 minutes after Step 5. Make another adjustment of the belt tension. The correct gauge indication for used belts is 90 ± 10. Tighten the bolts that hold the alternator.
5. Fill the cooling system with coolant to the correct level.

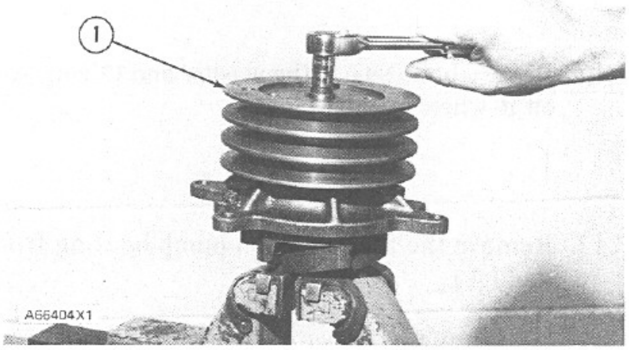


DISASSEMBLE WATER PUMP 1361-15

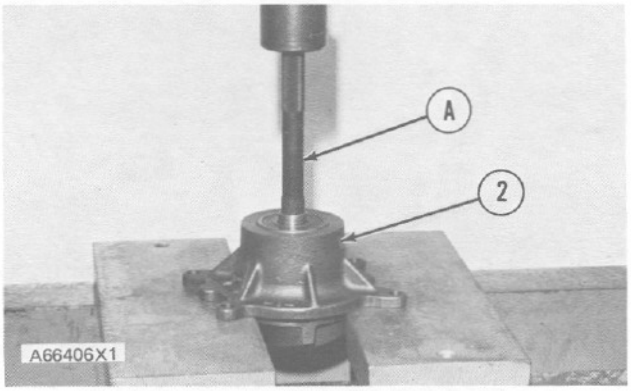
	Tools Needed	A	B	C
1P529	Handle	1		
1P460	Driver Plate	1		
1P1861	Pliers		1	
5P7354	Pin			1

a) remove water pump

1. Hold the pump shaft in a vise as shown and remove the bolt and pulley (1).



WATER PUMP

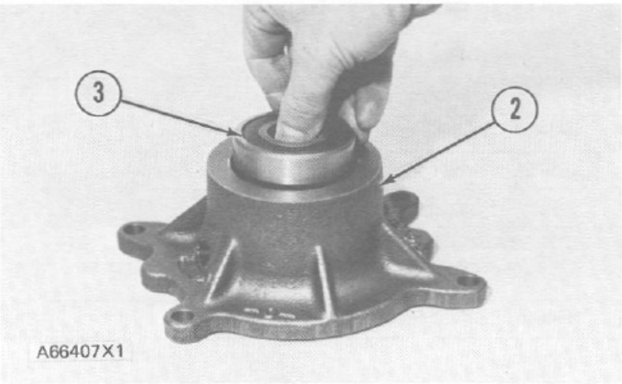


A66406X1

2. Use tooling (A) and a press to remove the shaft, seal and impeller from housing (2) as shown.

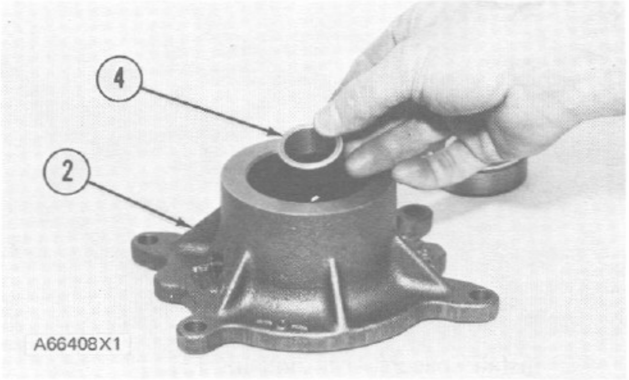
⚠ WARNING

The press must have a guard. The guard has been removed for photo illustration.



A66407X1

3. Remove bearing (3) from housing (2).

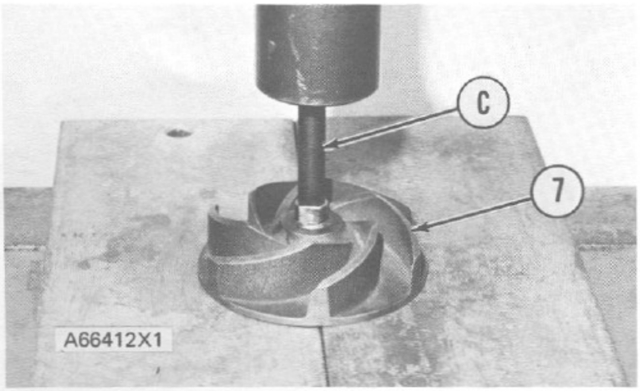


A66408X1

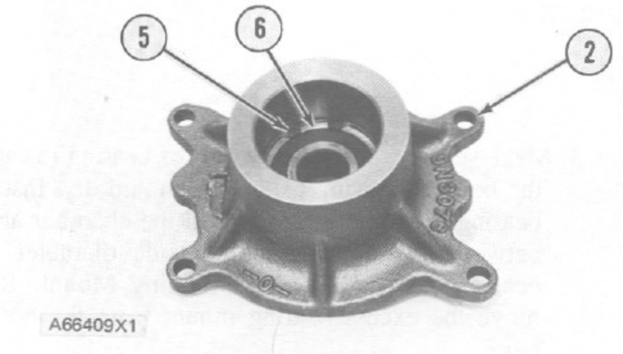
4. Remove spacer (4) from housing (2).

5. Use tool (B) to remove ring (5) from housing (2). Remove bearing (6) from housing (2).

6. Use a press and tool (C) to remove the shaft and seal assembly from impeller (7) as shown.



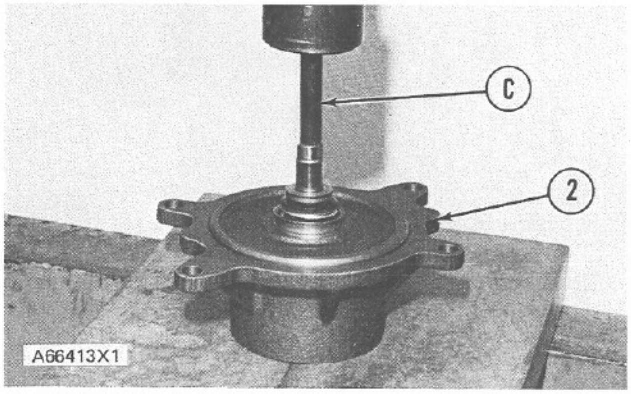
A66412X1



A66409X1

WATER PUMP

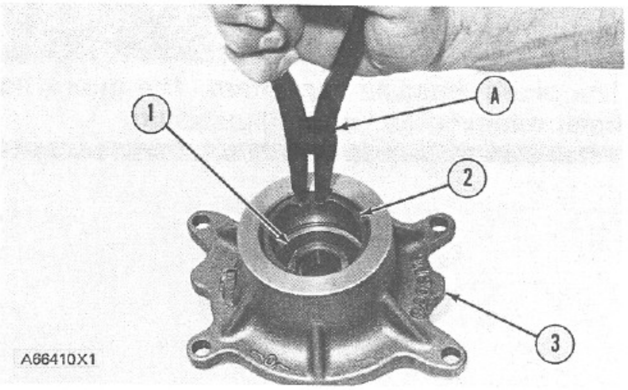
7. Install the seal assembly and shaft in housing (2) as shown. Use a press and tool (C) to remove the shaft from the seal assembly.



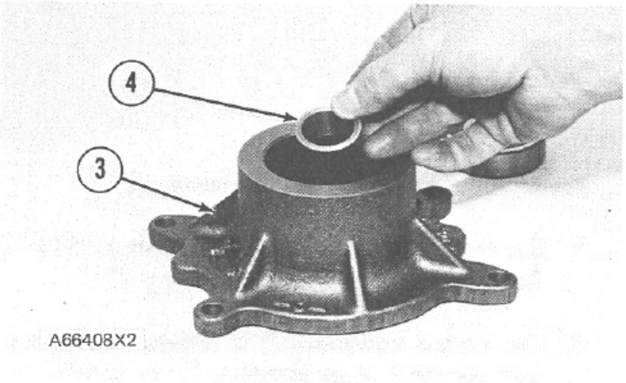
ASSEMBLE WATER PUMP 1361-16

Tools Needed		A	B	C	D	E
1P1861	Pliers	1				
5P9722	Driver		1			
5P7353	Spacer			1		
5P7352	Spacer				1	
1P529	Handle					1
1P460	Driver Plate					1

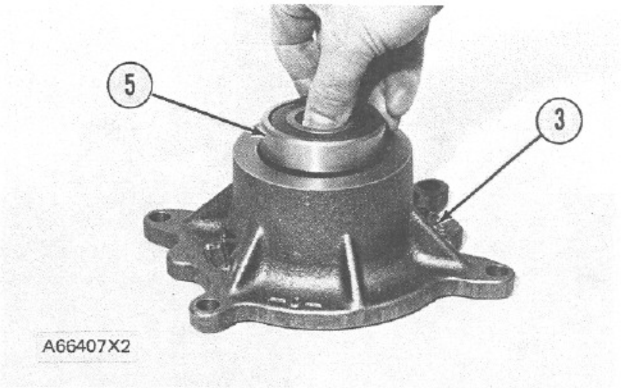
1 Install bearing (1) in housing (3). Use tool (A) to install ring (2) that holds bearing (1) in position.



2 Install spacer (4) in housing (3).



3 Make sure the outside diameter of bearing (5) and the bore in housing (3) are clean and dry. Install bearing (5) in housing (3). Fill the chamber area between the housing and outside diameter of bearing (5) with 7M7456 Bearing Mount. Remove the excess bearing mount from the housing.

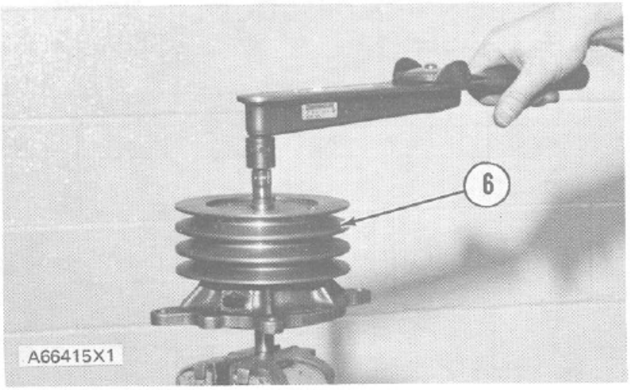


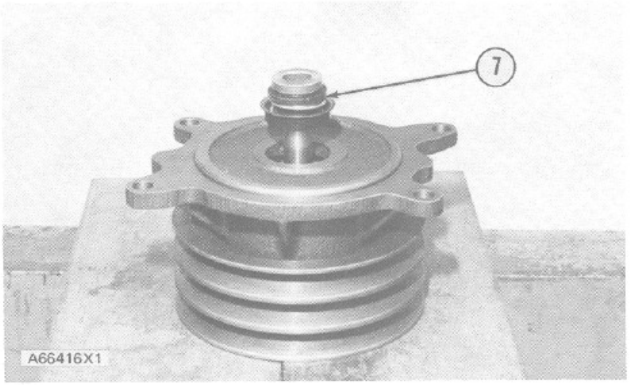
WATER PUMP

4. Turn the pump housing over and make sure that the bores in the bearings and spacer are in alignment. Install the shaft through the bearings from the impeller side of the housing.

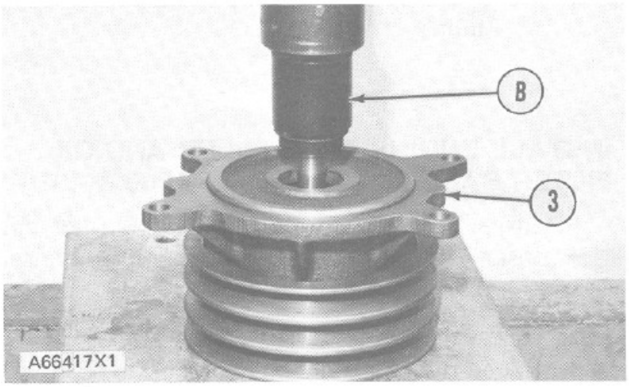
NOTE: The shaft to bearing clearance can be 0.018 mm (.0007 in.) loose to 0.008 mm (.0003 in.) tight. If it is necessary to use a press to install the shaft, make sure the inner races of the bearings have support.

5. Install pulley (6) on the shaft and tighten the bolt to a torque of 75 ± 7 N•m (55 ± 5 lb.ft.).





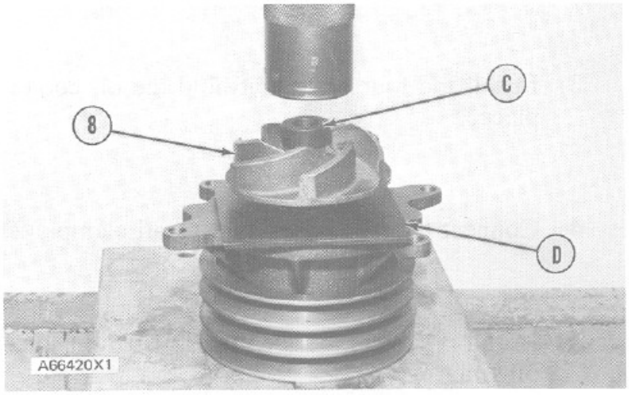
6. Put a new seal assembly (7) on the shaft as shown.



7. Use tool (B) and a press to install the seal assembly in housing (3). Do not use a hammer to install the seal.

8. Put tool (D) between impeller (8) and the pump housing.

9. Use a press and tool (C) to install impeller (8) on the shaft until tool (D) can just be moved between the housing and impeller.



10. If the impeller is installed too far and tool (D) cannot be removed, turn the pump over and remove the pulley. Use tooling (E) and press to push the shaft out of the bearings enough to remove tool (D). Install the pulley and tighten the bolt to a torque of 75 ± 7 N•m (55 ± 5 lb.ft.).

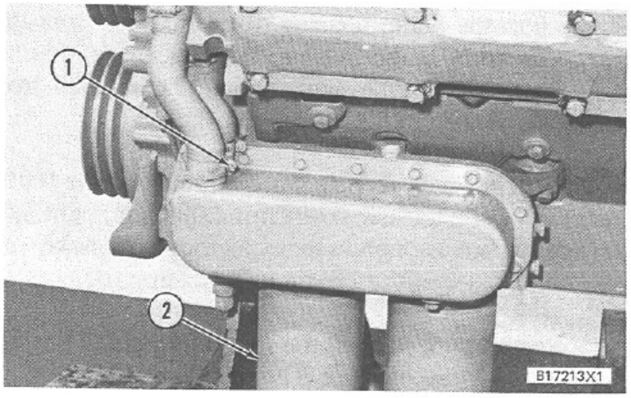
end by:
    a) install water pump

ENGINE OIL COOLER AND OIL FILTER BASE

REMOVE ENGINE OIL COOLER AND OIL FILTER BASE 1306 & 1378-11

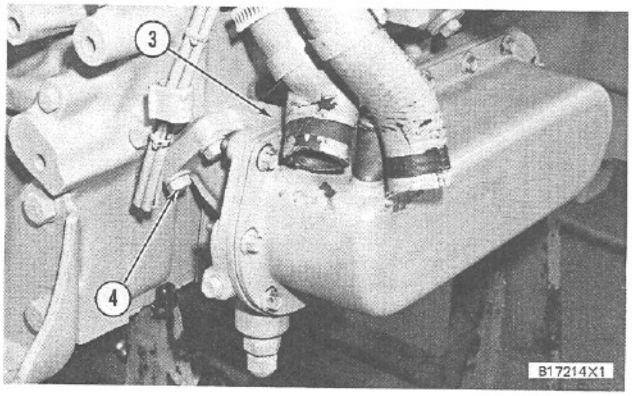
	Tools Needed	A
2P8250	Strap Wrench	1

NOTE: It is not necessary to remove the oil pan.



1. Remove the coolant from the cooling system.

2. Use tooling (A) and remove oil filter (2).

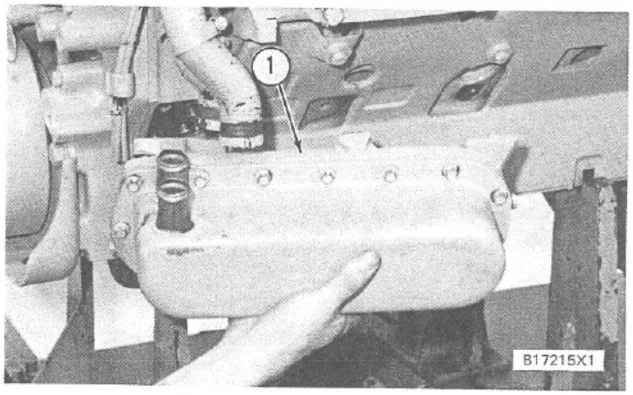


3. Loosen clamps (1) and disconnect the bases.

4. Remove bolt (4) and three bolts from behind the oil cooler.

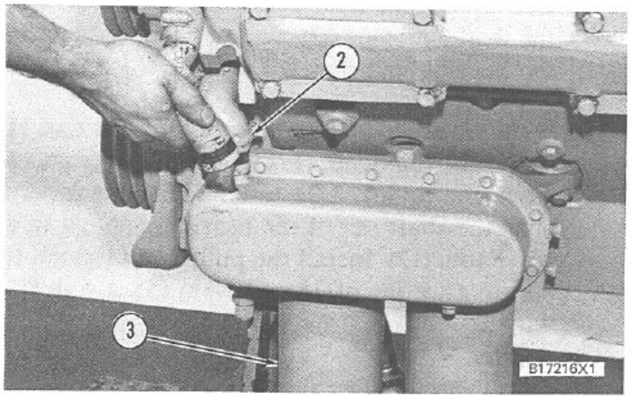
5. Remove oil filter base and engine oil cooler (3) as a unit.

INSTALL ENGINE OIL COOLER AND OIL FILTER BASE 1306 & 1378-12



1. Inspect the O-ring seals in the oil filter base. Install new seals if needed. Put oil on the seal.

2. Put oil filter base and oil cooler (1) in position on the engine.



3. Install the four bolts that hold the oil cooler in place.

4. Connect the two hoses and install clamps (2).

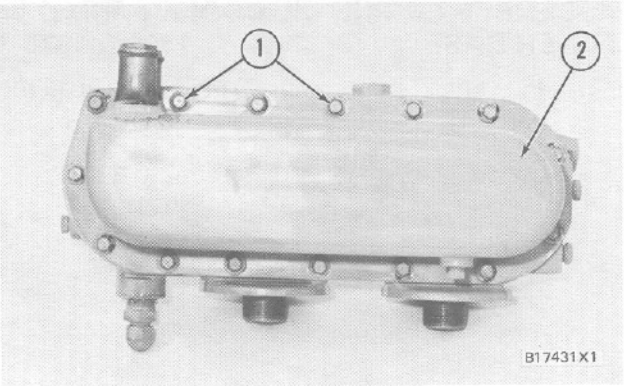
5. Install oil filters (3). See the instructions on the oil filter.

ENGINE OIL COOLER AND OIL FILTER BASE

DISASSEMBLE ENGINE OIL COOLER AND OIL FILTER BASE 1306 & 1378-15

start by:
a) remove engine oil cooler and oil filter base

1. Remove bolts (1) and make a separation of cover (2) from the oil filter base.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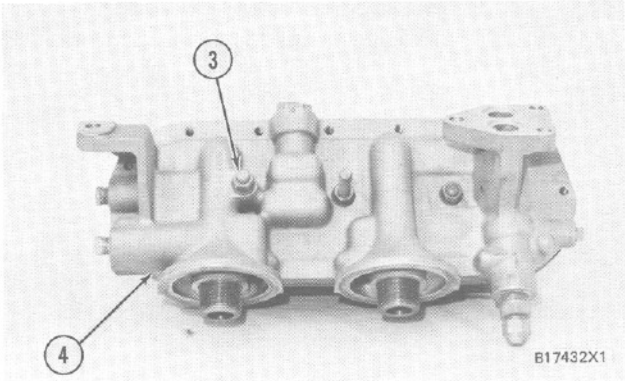
2
B17431X1

2. Remove nuts (3) and make a separation of the oil cooler from oil filter base (4).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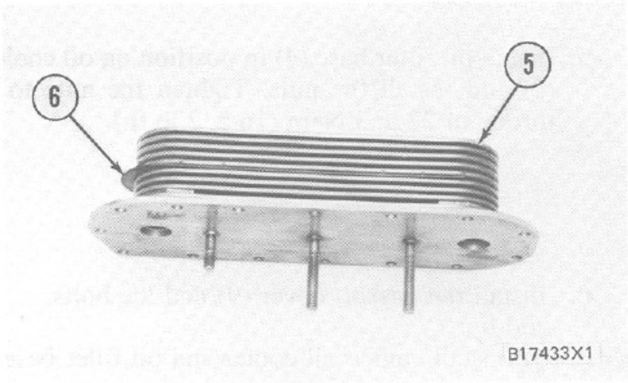
3. Remove divider (6) from oil cooler (5).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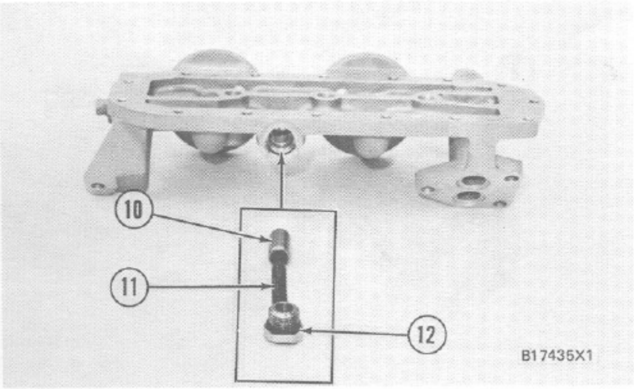
B17433X1

4. Remove plug (9), spring (8) and bypass valve (7).

5. Remove plug (12), spring (11) and bypass valve (10) from the oil filter base.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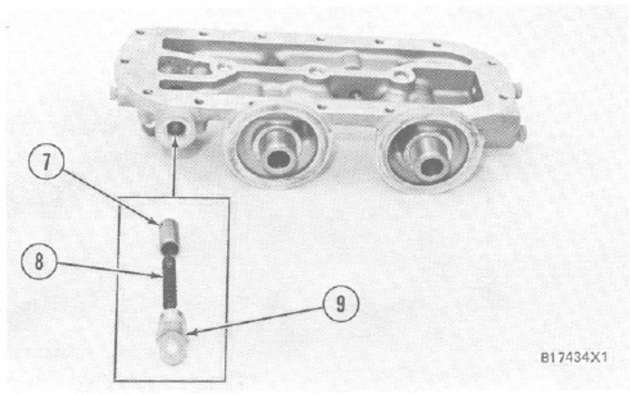
B17435X1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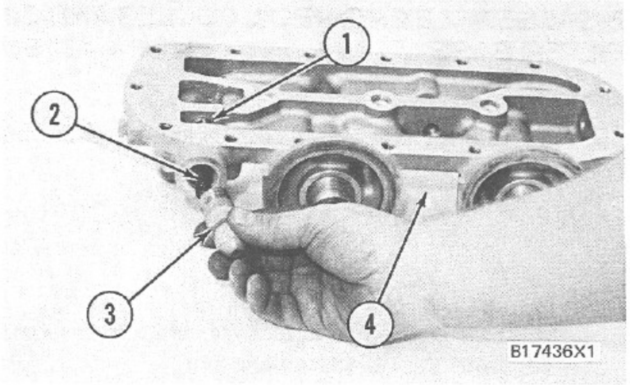
B17434X1

ENGINE OIL COOLER AND OIL FILTER BASE

ASSEMBLE ENGINE OIL COOLER AND OIL FILTER BASE 1306 & 1378-16

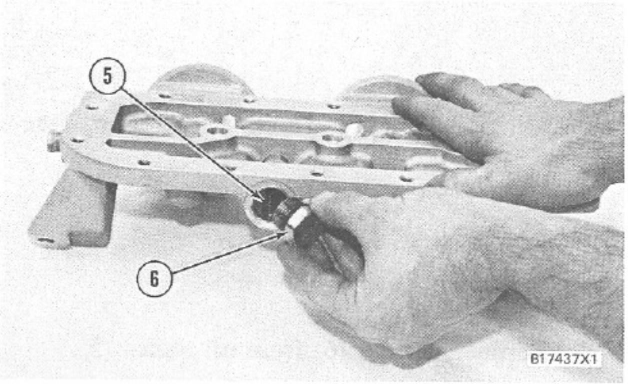
1. Put valve (1) and spring (2) in position in oil filter base (4).



B17436X1

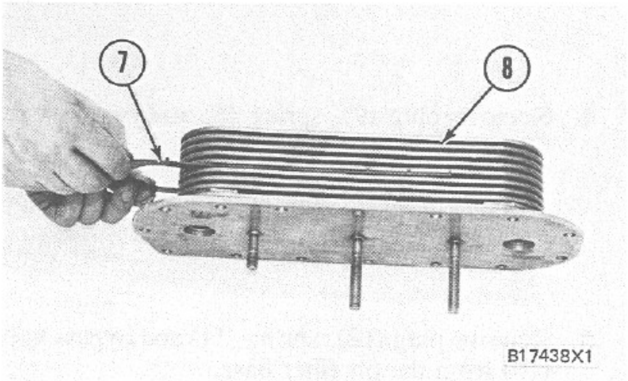
2. Install plug (3).

3. Put the valve and spring (5) in position and install plug (6).



B17437X1

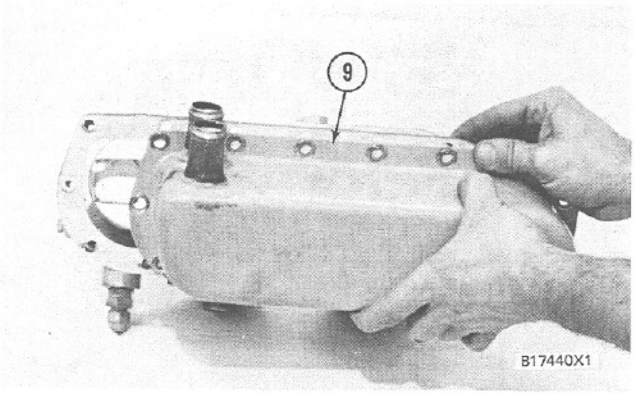
4. Put divider (7) in position between the fifth and sixth plates from the flange and on the same end as the short stud.



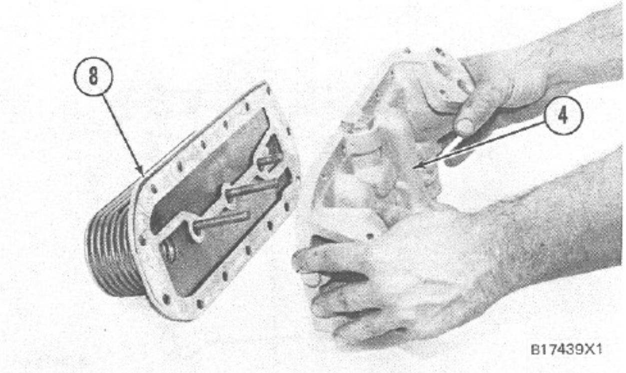
B17438X1

5. Install oil filter base (4) in position on oil cooler (8) and install the nuts. Tighten the nuts to a torque of 22 ± 3 N•m (16 ± 2 lb.ft.).

6. Install the gasket, cover (9) and the bolts.
   end by:
   a) install engine oil cooler and oil filter base



B17440X1

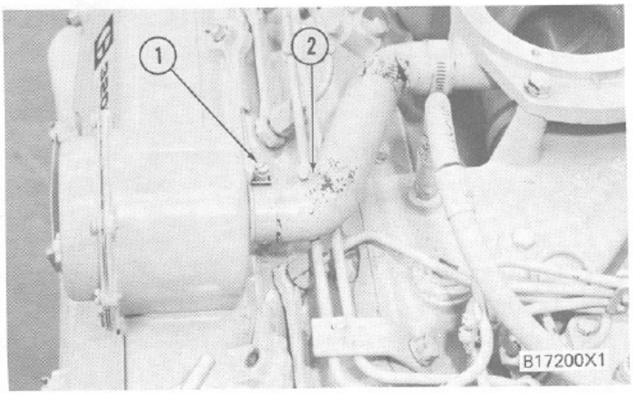


B17439X1

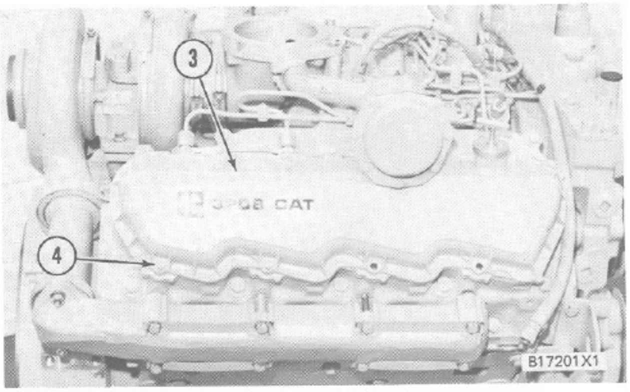
VALVE COVERS

REMOVE VALVE COVERS 1107-11

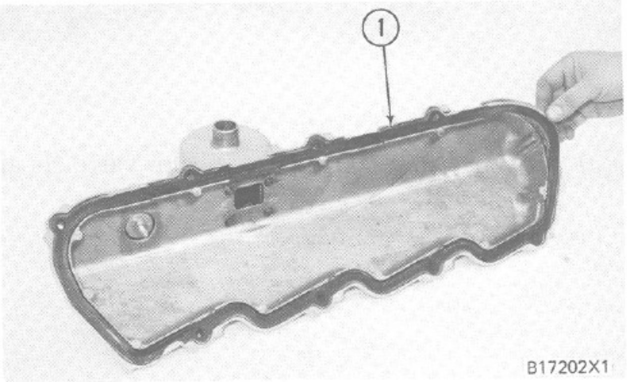
start by:
a) remove water separator


1
2
B17200X1

1. Loosen clamp (1). Slide hose (2) away from the crankcase ventilation valve.


3
4
3208 CAT
B17201X1

2. Remove bolts (4) and valve cover (3).

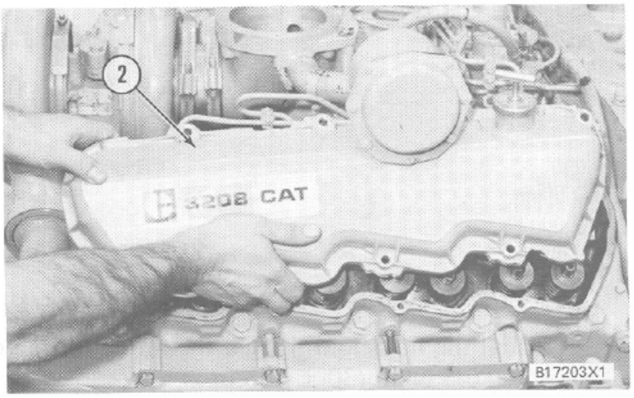


3. Remove the gasket from the valve cover.

4. Do Steps 1 through 3 for the other valve cover.

INSTALL VALVE COVERS 1107-12

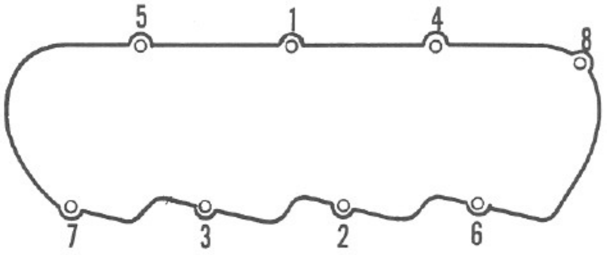
1. Put gasket (1) in position in the valve cover.


2
3208 CAT
B17203X1

2. Put valve cover (2) in position. Install the bolts.

VALVE COVERS, CRANKCASE VENTILATOR VALVE

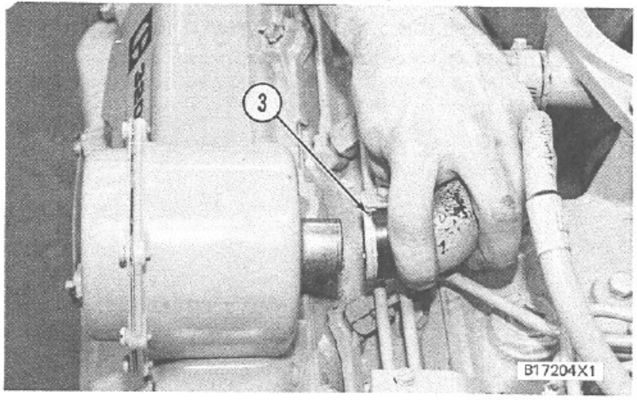
3. Tighten the bolts to a torque of 14 ± 3 N•m (120 ± 24 lb.in.) in the sequences shown.



TIGHTENING SEQUENCE

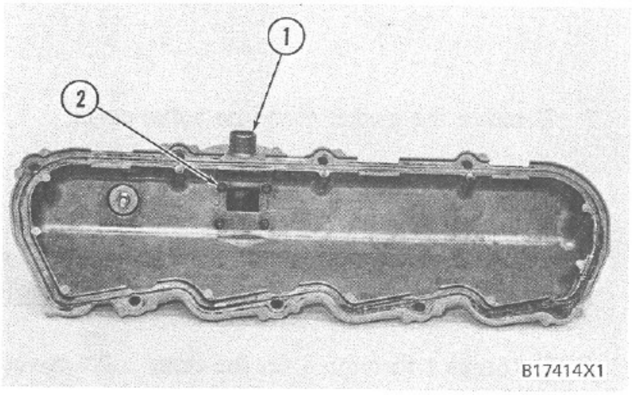
4. Connect hose (3) to the crankcase ventilator valve. Put the hose clamp in position. Tighten the hose clamp to a torque of 2.3 ± 0.2 N•m (20 ± 2 lb.in.).

   end by:
   a) install water separator



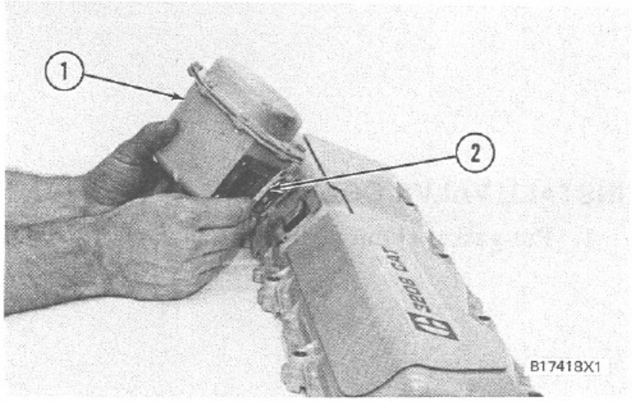
REMOVE CRANKCASE VENTILATOR VALVE 1074-11

start by:
a) remove valve covers



1. Remove four bolts (2), ventilator valve (1) and the gasket.

INSTALL CRANKCASE VENTILATOR VALVE 1074-12



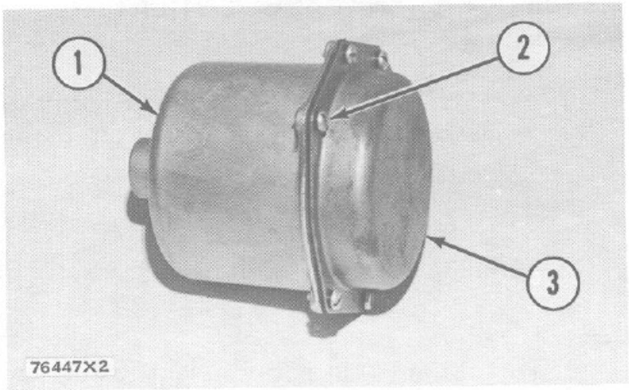
1. Put gasket (2) and ventilator valve (1) in position.

2. Install the bolts and tighten them to a torque of 3.4 ± 0.5 N•m (30 ± 4 lb.in.).

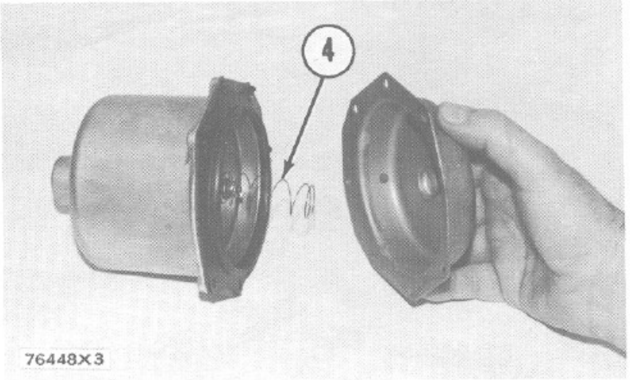
CRANKCASE VENTILATOR VALVE

DISASSEMBLE CRANKCASE VENTILATOR VALVE 1074-15

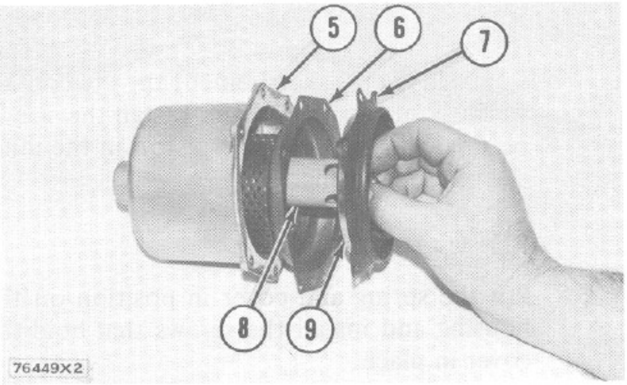
NOTE: The crankcase ventilator valve can be disassembled while installed on the engine. The valve was removed for better photo illustration.



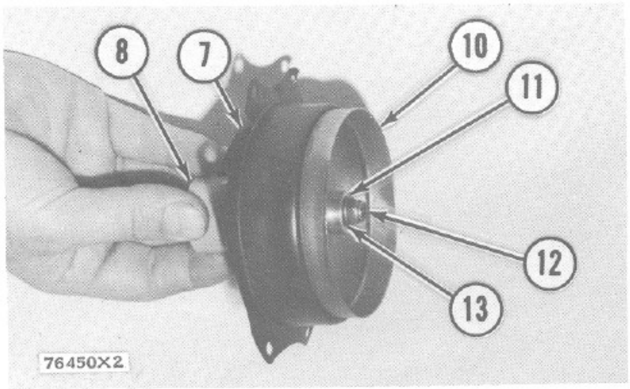
1. Remove screws (2) that hold cover (3) on housing (1).



2. Remove cover (3) and spring (4) from the housing.



3. Remove the piston, sleeve (8), retainer (9), and diaphragm (7) from the housing as a unit.



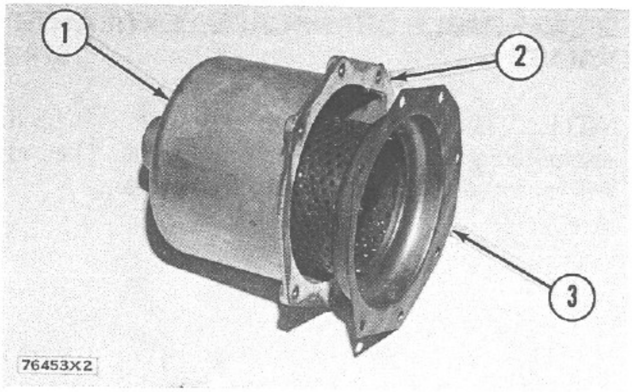
4. Remove inner sleeve (6) and gasket (5) from the housing.

5. Remove nut (12), washer (13), spacer (11), piston (10), diaphragm (7), and the retainer from sleeve (8).

CRANKCASE VENTILATOR VALVE

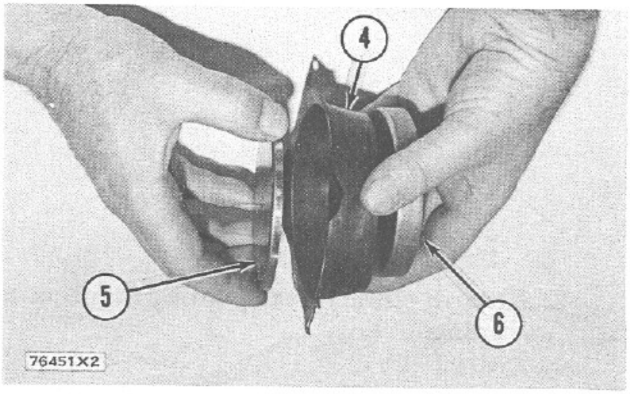
ASSEMBLE CRANKCASE VENTILATOR VALVE 1074-16

1. Put 5H2471 Gasket Cement on both sides of gasket (2). Install the gasket on housing (1).



2. Install inner sleeve (3) in the housing.

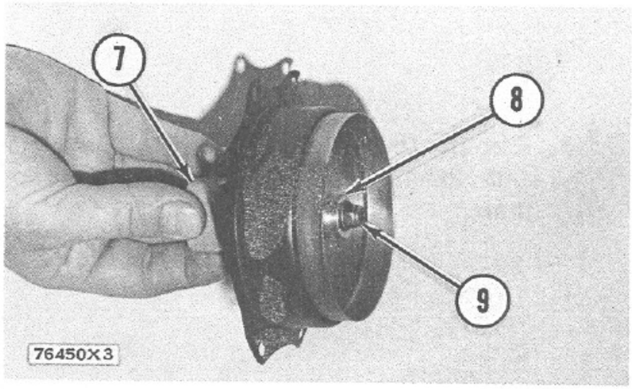
3. Put piston (6) in position next to the side of diaphragm (4) that has identification "PISTON SIDE".



4. Put retainer (5) in the diaphragm.

5. Put the screw through sleeve (7), retainer, diaphragm, and the piston.

6. Install spacer (8), washer, and nut (9) on the screw.



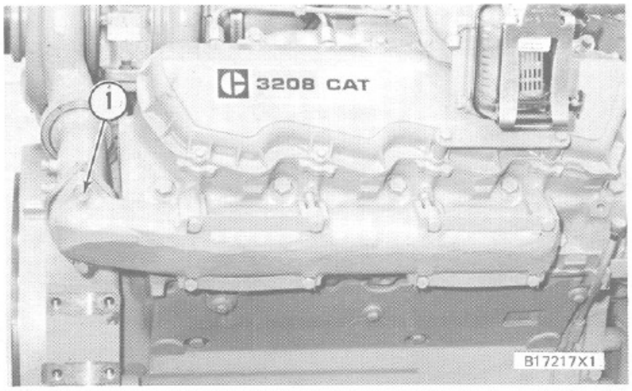
7. Put 5H2471 Gasket Cement on the contact surfaces of the diaphragm. Install the sleeve, retainer, diaphragm, and piston in the inner sleeve and housing.

8. Put the spring and cover in position on the housing and install the screws that hold the cover in place.

EXHAUST MANIFOLD

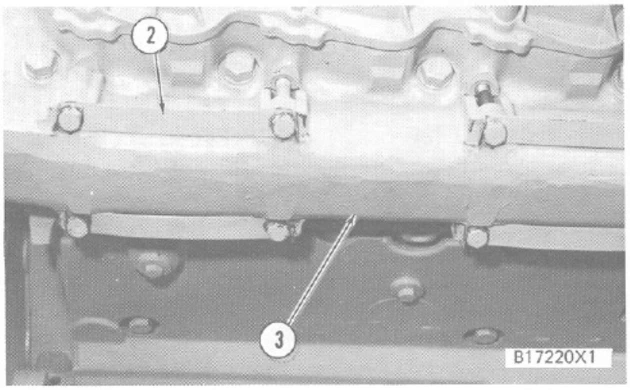
REMOVE EXHAUST MANIFOLD 1059-11

1. Remove two bolts (1) from the flanges.


1
3208 CAT
B17217X1

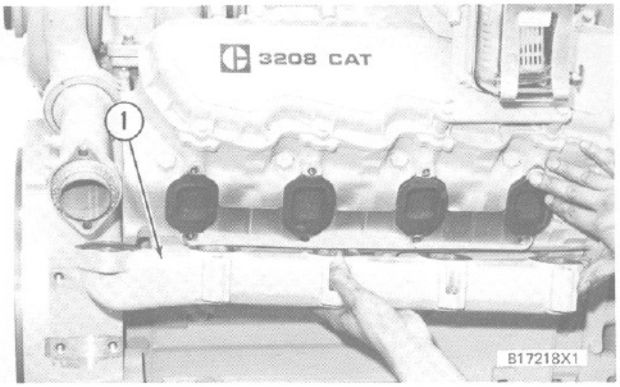
2. Bend the tabs back on locks (2).

3. Remove the bolts, exhaust manifold (3) and the gasket.


2
3
B17220X1

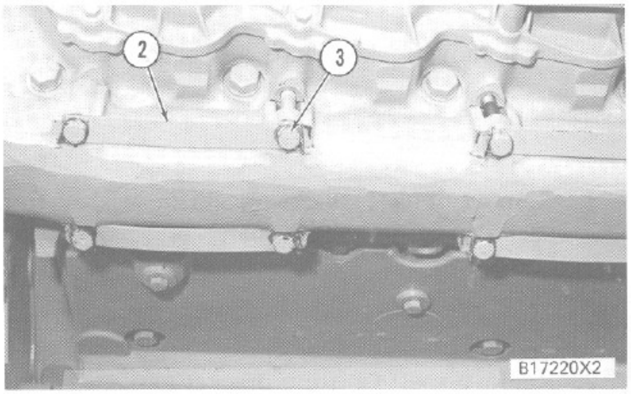
INSTALL EXHAUST MANIFOLD 1059-12

1. Put the gasket and exhaust manifold (1) in position.


3208 CAT
1
B17218X1

NOTE: Put 5P3931 Anti-Seize Compound on the bolt threads.

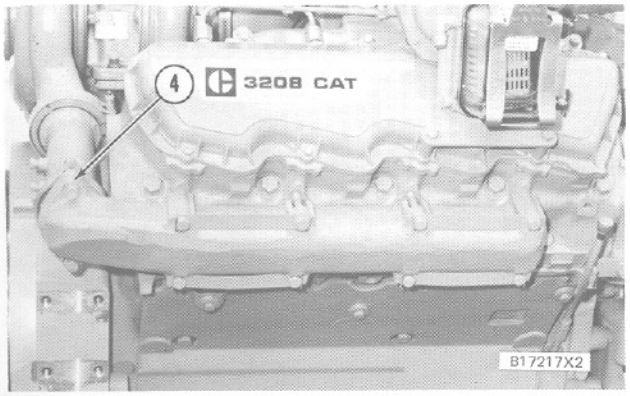
2. Install locks (2) and bolts (3).


2
3
B17220X2

3. Tighten the bolts to a torque of 43 ± 7 N•m (32 ± 5 lb.ft.).

NOTE: The locks must be bent on a flat side of the bolt head. Bolts must be turned no more than 30° of a turn (in the direction of increased torque only) for the alignment of the locks with a flat side of the bolt head.

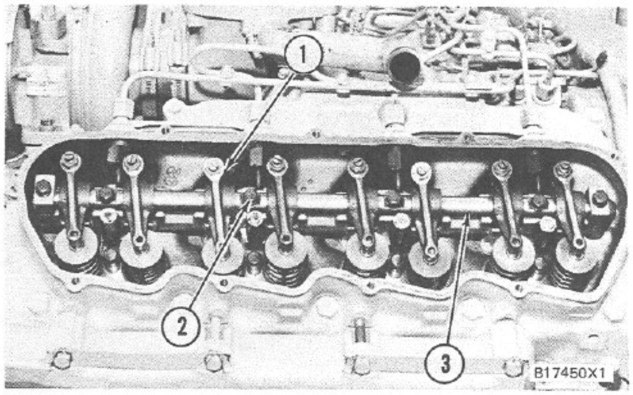
4. Put bolts (4) and the flange in position. Install the nuts.


4
3208 CAT
B17217X2

ROCKER SHAFTS AND PUSH RODS, ROCKER SHAFTS

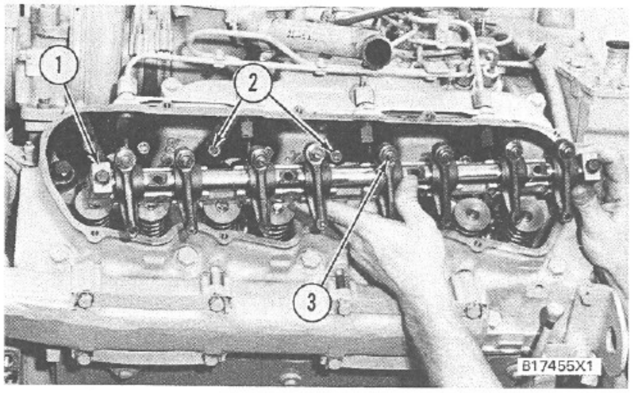
REMOVE ROCKER SHAFTS AND PUSH RODS 1102 & 1208-11

start by:
a) remove the valve covers



1. Remove bolts (2) from rocker shaft (3) and remove rocker shaft. Remove push rods (1).

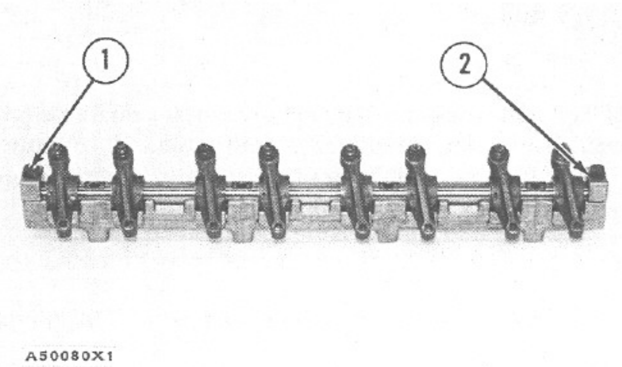
INSTALL ROCKER SHAFTS AND PUSH RODS 1102 & 1208-12



1. Install push rods (2). Put rocker shaft (1) in position on the engine. Tighten the bolts to a torque of 24 ± 7 N•m (18 ± 5 lb.ft.).

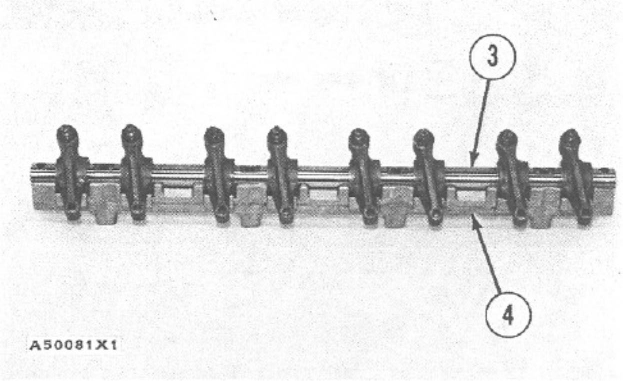
2. Make adjustment until the intake valve clearance is 0.38 mm (.015 in.) and the exhaust valve clearance is 0.64 mm (.025 in.). Tighten nuts (3) to a torque of 30 ± 7 N•m (24 ± 5 lb.ft.).

end by:
a) install valve covers



DISASSEMBLE ROCKER SHAFTS 1102-15

start by:
a) remove rocker shafts and push rods



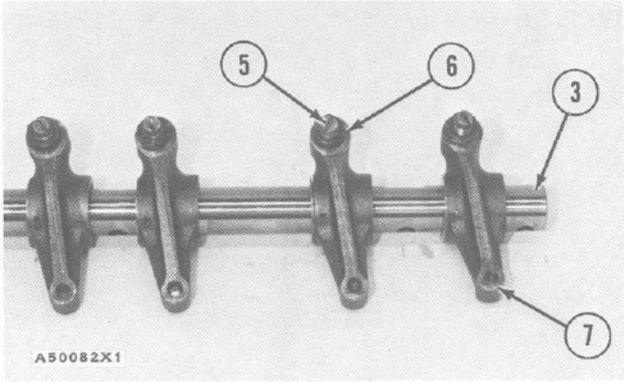
1. Remove bolts (1), locks (2) and the washers from each end of the rocker shaft.

2. Remove shaft (3) from bracket (4).

ROCKER SHAFTS

3. Remove rocker arm assemblies (7) and the washers from shaft (3).

4. Remove screw (5) and nut (6) from rocker arm assemblies (7).



ASSEMBLE ROCKER SHAFTS 1102-16

1. Make sure the oil holes in the rocker arm assemblies, rocker shaft and bracket are clean and free of all dirt and foreign material.

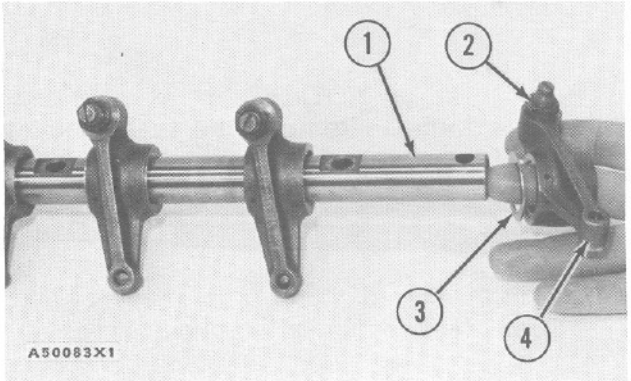
2. Measure the bore of the bushing in each of the rocker arms. The bore must be 21.852 ± 0.020 mm (.8603 ± .0008 in.). The maximum permissible bore is 21.920 mm (.8630 in.).

NOTE: Make a replacement of the arm and bushing as a unit if the bore is not correct. The arms and bushings can not be ordered separately.

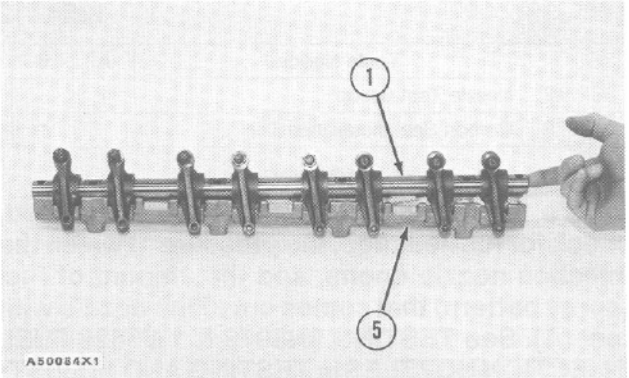
3. Measure the diameter of the shaft at each of the rocker arm locations. The diameter must be 21.793 to 21.814 mm (.8580 to .8588 in.). The minimum permissible diameter is 21.768 mm (.8570 in.).

4. Install the screws and nuts (2) into rocker arm assemblies (4). Turn the screws until they are 11.2 mm (.44 in.) below the bottom of the rocker arm assemblies.

5. Install the rocker arm assemblies and washers (3) on shaft (1) as shown.

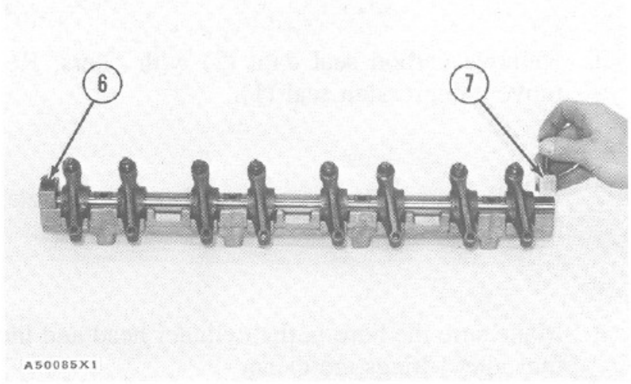


6. Put shaft (1) and the rocker arm assemblies in position on bracket (5) with the adjustment screws on the same side as the oil hole on the bottom of the bracket.



7. Make sure the flat surfaces on shaft (1) are turned up. Install locks (7), the washers and bolts (6). Tighten the bolts to a torque of 24 ± 7 N•m (18 ± 5 lb.ft.).

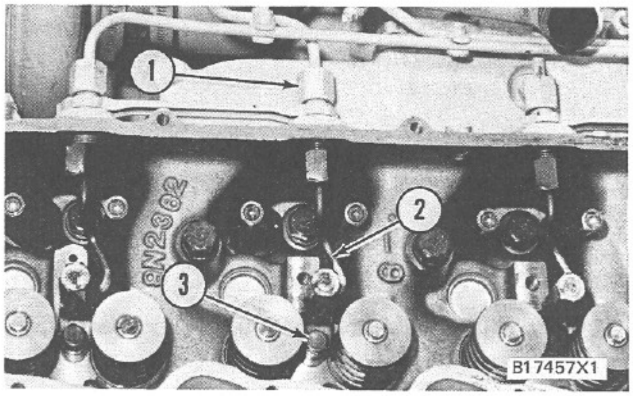
   end by:
   a) install rocker shafts and push rods



FUEL INJECTION NOZZLES

REMOVE FUEL INJECTION NOZZLES (9N3979 & 1W5829) 1254–11

start by:
a) remove rocker shafts

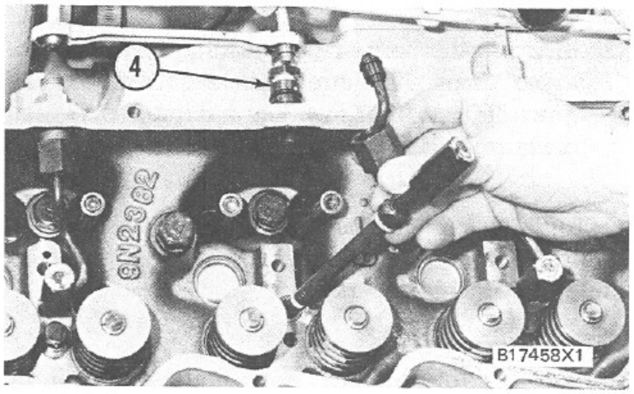


1. Thoroughly clean the area around each fuel line connection. Disconnect fuel injection line (1) from the adapter. Disconnect fuel injection nozzle (2) from the adapter.

2. Remove clamp (3) and the spacer that holds the fuel injection nozzle in place.

NOTICE

Never use force to remove the fuel injection nozzles. If necessary, turn and pull the fuel injection nozzle out of the cylinder head.



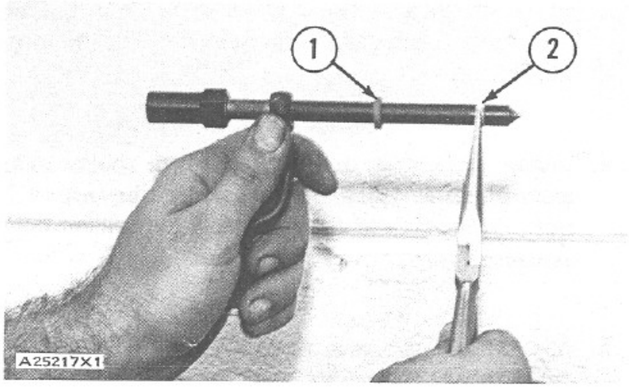
3. Remove the adapter (4) from the cylinder head. Remove the fuel injection nozzle.

INSTALL FUEL INJECTION NOZZLES (9N3979 & 1W5839) 1254–12

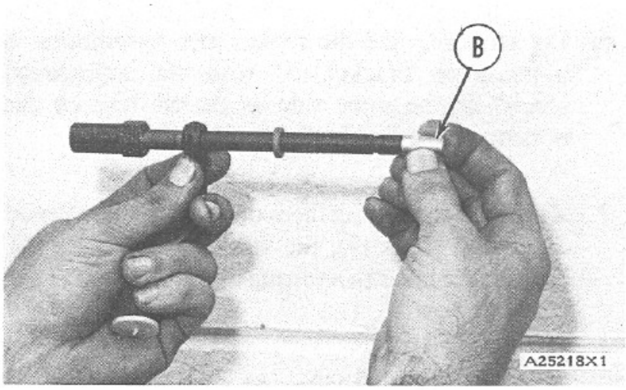
Tools Needed		A	B
8S2242	Nozzle Test Group	1	
6V4979	Carbon Seal Installation Tool		1

NOTICE

Before the fuel injection nozzles are installed, check for fuel leakage, the pressure at which the injection nozzle opens, and the amount of fuel (spray pattern) that comes out of the nozzle with tool (A). See TESTING 9N3979 & 1W5829 FUEL INJECTION NOZZLES in TESTING AND ADJUSTING.



1. Remove carbon seal dam (2) with pliers. Remove compression seal (1).



2. Install a new compression seal on the nozzle. Install a new carbon seal dam with tool (B).

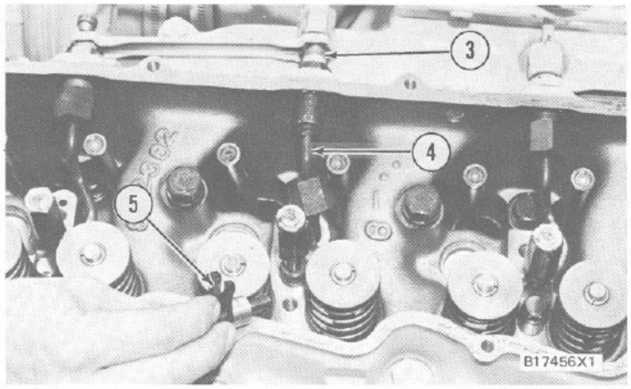
3. Make sure the bore in the cylinder head and the fuel inlet fittings are clean.

FUEL INJECTION NOZZLES

4. Install new O-ring seals on adapter (3) and fuel injection nozzle (4).
5. Install the fuel injection nozzle in the head. Turn and push the nozzle into its correct position. Never put lubricant on the nozzle or bore in the cylinder head.
6. Install the adapter in the head. Connect the nozzle and fuel injection line to the adapter. Tighten the nuts to a torque of 40 ± 7 N•m (30 ± 5 lb.ft.).
7. Install the spacer and clamp (5) that hold the nozzle to the cylinder head.

end by:

a) install rocker shafts



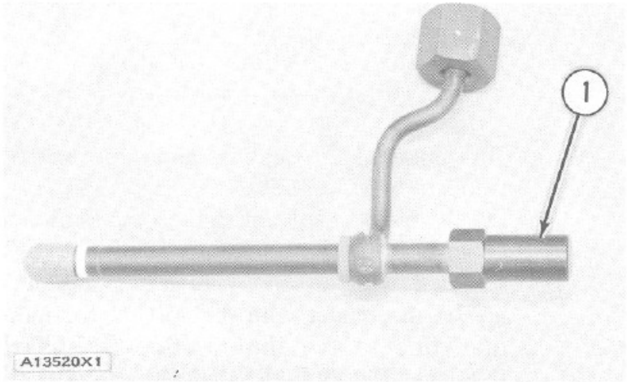
DISASSEMBLE FUEL INJECTION NOZZLES (9N3979 & 1W5829) 1254-15

	Tools Needed	A	B	C	D
8S2242	Nozzle Test Group	1			
8S2250	Nozzle Holding Tool		1		
5P958	Valve Retractor			1	
5P4813	Socket				1

start by:

a) remove fuel injection nozzles

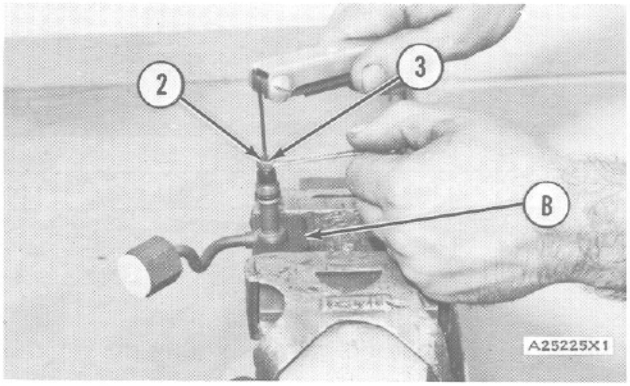
NOTE: Do not disassemble any nozzle until test has shown it is needed. Check each nozzle with tool (A) for leakage, the pressure, at which the nozzle opens, and the shape and amount of fuel (spray pattern) that comes out of the nozzle. Do not clean or make an adjustment to any nozzle that has a large (excessive) amount of return leakage. Excessive return leakage can be an indication of nozzle failures that cannot be corrected with an adjustment or cleaning and can cause engine damage. See TESTING 9N3979 & 1W5829 FUEL INJECTION NOZZLES in TESTING AND ADJUSTING.



NOTICE

Keep the work area and all tools extra clean. Be careful not to cause damage to the parts while the nozzles are disassembled and assembled.

1. Remove cap (1) from the fuel injection nozzle.
2. Put the nozzle in tool (B). Put tool (B) and the nozzle in a vise. Do not put any part of a nozzle directly in a vise. Loosen locknut (2) while the lift adjustment screw is held. Turn the lift adjustment screw (3) counterclockwise one turn. Hold the lift adjustment screw (3) with a 5/64" hex wrench and remove the locknut (2).

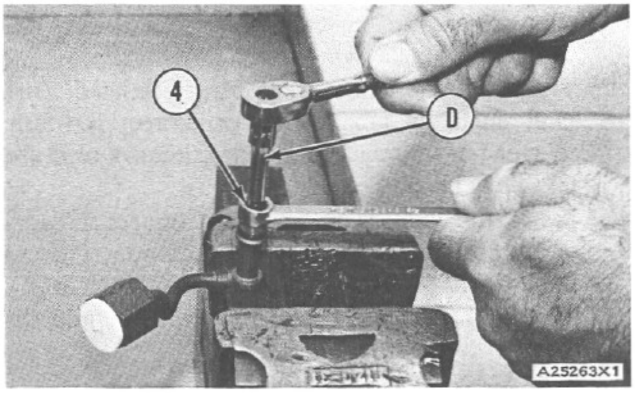


NOTICE

If the lift adjustment screw is not turned counterclockwise one turn, the valve can be bent or the seat for the valve can be damaged when the pressure adjustment screw is turned.

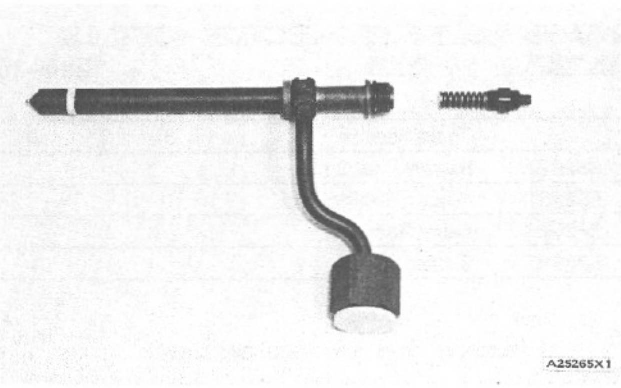
FUEL INJECTION NOZZLES

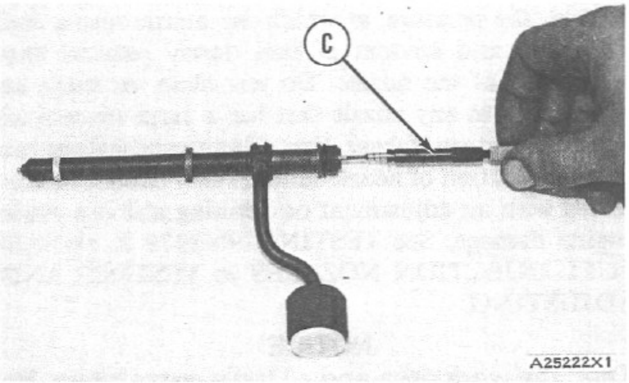
3. Loosen the locknut (4) that holds the pressure adjustment screw. Use tool (D) to hold the pressure adjustment screw.



4. While the nozzle is held in one hand, tilt the nozzle and remove the pressure adjusting screw and locknut, spring, seat and valve.

5. If the valve does not slide out of the nozzle, install tool (C) and remove valve as follows:
   a) Push valve into nozzle with tool (C) until valve is against bottom of nozzle.
   b) Push down on body of tool (C) to engage collet on valve with tool (C).
   c) Turn nut counterclockwise and remove valve from the nozzle body.
   Put the parts in solvent to loosen carbon and deposits of foreign material. The body is assembled with an epoxy material and must not be in contact with the solvent for more than one to two hours. See SPECIAL INSTRUCTION FORM NO. SEHS7292 for the correct method of cleaning the nozzle.





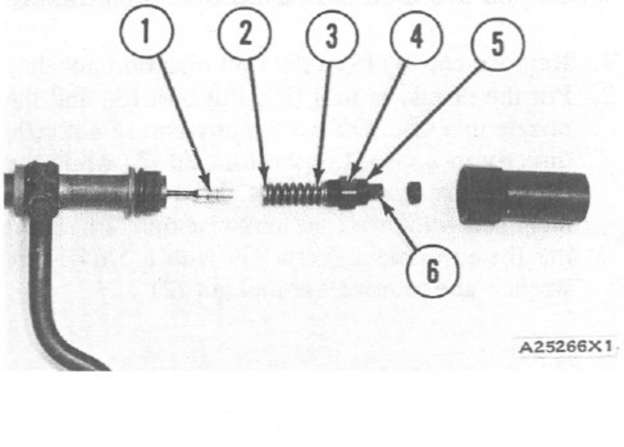
ASSEMBLE FUEL INJECTION NOZZLES (9N3979 & 1W5829)

1254–16

	Tools Needed	A	B	C
8S2250	Nozzle Holding Tool	1		
8S2242	Nozzle Test Group		1	
9S5031	Socket			1

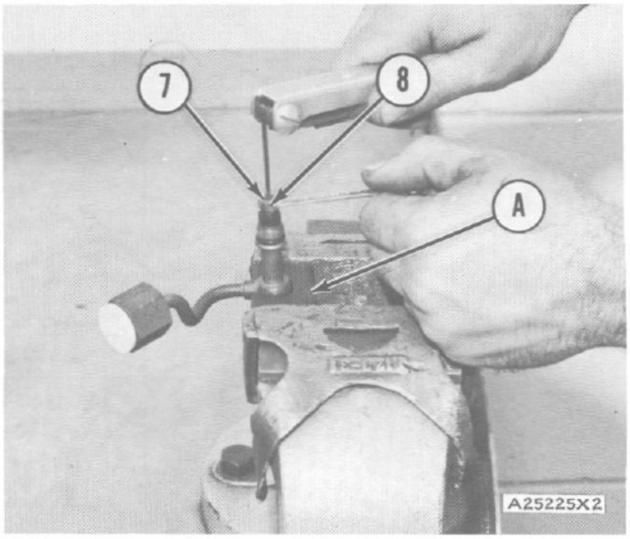
NOTE: Make sure all of the parts have been thoroughly cleaned before assembling the nozzles. Flush the body to remove any debris or lapping compound.

1. Put clean fuel on all of the parts.
2. Put valve (1) in position in the body as shown.
3. Install lift adjusting screw (6) into pressure screw (5). Turn the lift adjusting screw two or three turns. Install the locknut (4) on the pressure adjusting screw (5).
4. Put spring (3), and seat (2) in position on the adjusting screw (5).
5. Put seat (2) in contact with the valve and push the valve into position in the body. Tighten the pressure screw by hand.



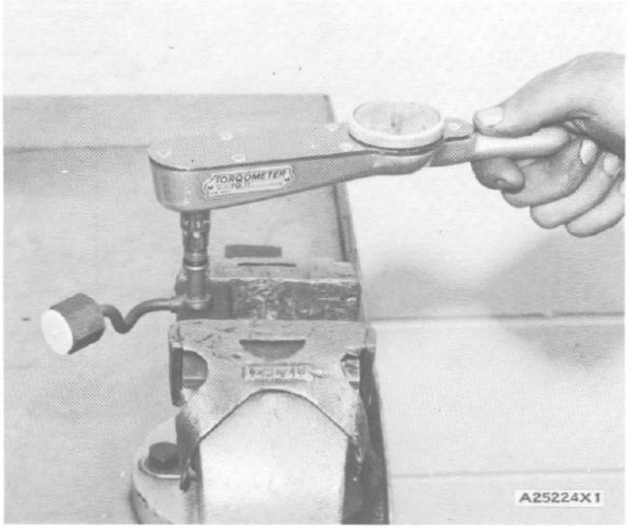
FUEL INJECTION NOZZLES

6. Make an adjustment to the opening pressure of the nozzle as controlled by the pressure adjusting screw with tool (B). See TESTING (9N3979 & 1W5829) FUEL INJECTION NOZZLES, OPENING PRESSURE TEST in TESTING AND ADJUSTING.



7. Make an adjustment to the valve lift as controlled by the lift adjusting screw with tool (B). See TESTING (9N3979 & 1W5829) FUEL INJECTION NOZZLES, VALVE LIFT ADJUSTMENT in TESTING AND ADJUSTING.

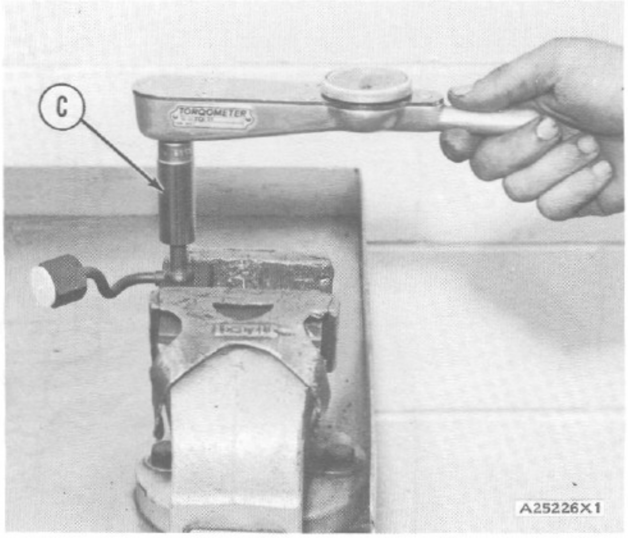
8. Put the nozzle in position in tool (A). Put tool (A) and the nozzle in a vise. Hold the lift adjustment screw (7) with a 5/64" hex wrench and tighten the locknut (8) until the adjusting screw will not turn.



9. Tighten the locknut for the pressure adjustment screw to a torque of 8.0 to 9.1 N•m (70 to 80 lb.in.).

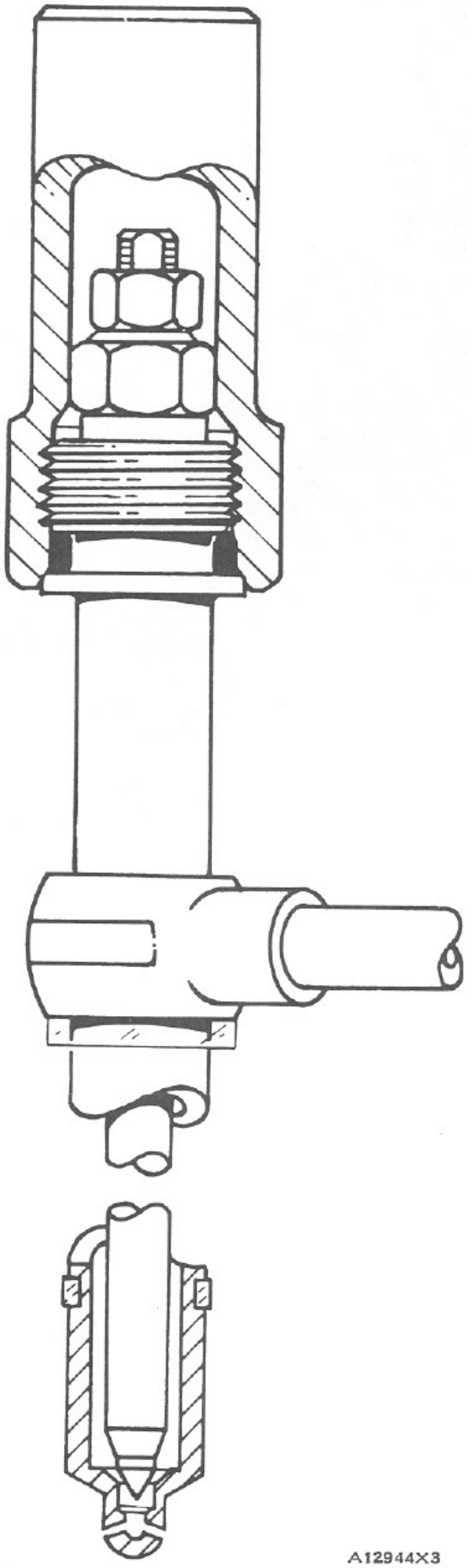
10. Tighten the locknut for the pressure adjustment screw to a torque of 4.0 to 5.1 N•m (35 to 45 lb.in.).

11. Install the cap on the fuel injection nozzle. Use tool (C) to tighten the cap to a torque of 12.4 to 13.6 N•m (110 to 120 lb.in.).



end by:
  a) install fuel injection nozzle

FUEL INJECTION NOZZLES



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FUEL INJECTION NOZZLES

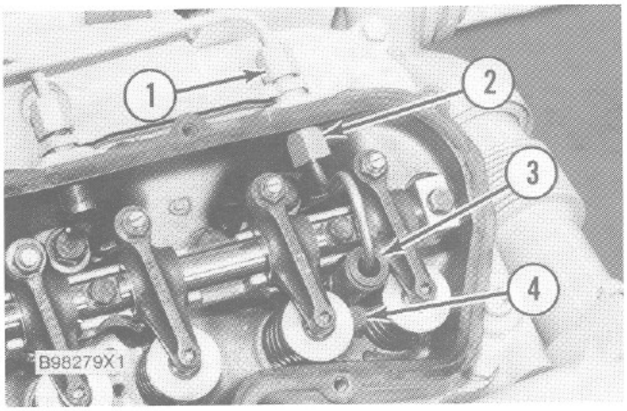
REMOVE AND INSTALL 7000 SERIES FUEL INJECTION NOZZLES 1254-010

Tools Needed		A	B
8S2242	Nozzle Test Group	1	
6V4979	Carbon Seal Installation Tool		1

start by:

a) remove valve covers

1. Thoroughly clean the area around each of the fuel line connections. Disconnect fuel line connection (1). Disconnect fuel injection nozzle fitting (2) from the adapter.



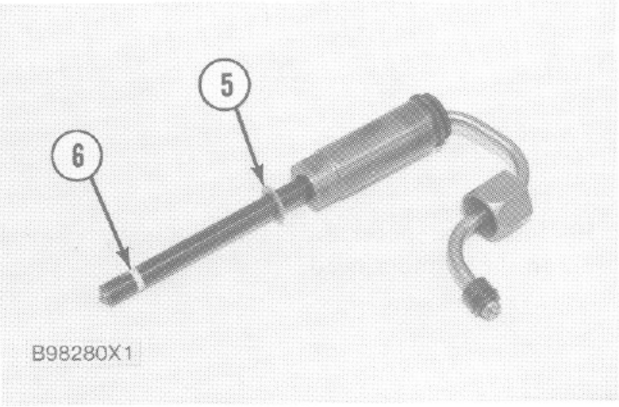
2. Remove bolt (4), the clamp and spacer that hold the fuel injection nozzle in place.

NOTICE

Never use force to remove the fuel injection nozzles. If necessary, turn and pull the fuel injection nozzles out of the cylinder head.

3. Slide the adapter from the cylinder head, and remove fuel injection nozzles (3).

4. Remove carbon seal dam (6) and compression seal (5).



NOTE: The following steps are for installation of the fuel injection nozzles.

NOTICE

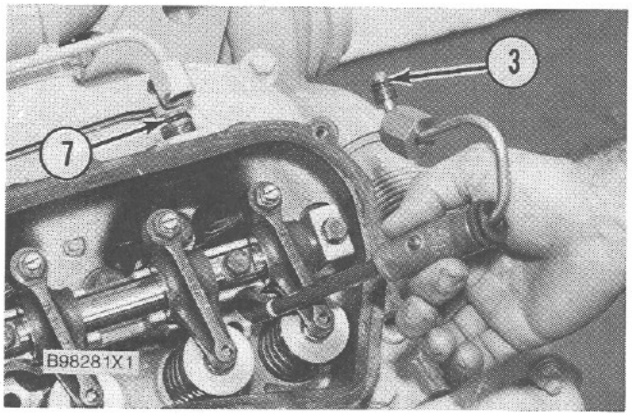
Before the fuel injection nozzles are installed, check for fuel leakage, the pressure at which the injection nozzle opens, and the amount of fuel (spray pattern) that comes out of the nozzle with tool (A). See Testing 7000 Series Fuel Injection Nozzles in Testing And Adjusting.

5. Install a new compression seal (5). Install a new carbon seal dam (6) with tool (B).

6. Make sure the bore in the cylinder head and the fuel inlet fittings are clean.

FUEL INJECTION NOZZLES

7. Install new O-ring seals on adapter (7) and fuel injection nozzle (3).



8. Install the fuel injection nozzle in the cylinder head. Never put lubricant on the nozzle or bore in the cylinder head.

9. Install the adapter in the cylinder head. Connect the nozzle and fuel injection line to the adapter. Tighten the nuts to a torque of 40 ± 7 N•m (30 ± 5 lb.ft.).

10. Install the spacer and clamp that hold the nozzles in the cylinder head.

end by:

a) install valve covers

CYLINDER HEADS

REMOVE CYLINDER HEADS 1101-11

Tools Needed		A	B
6V7860	Water Sleeve Tool	1	
5P9736	Bracket-Link		2

start by:

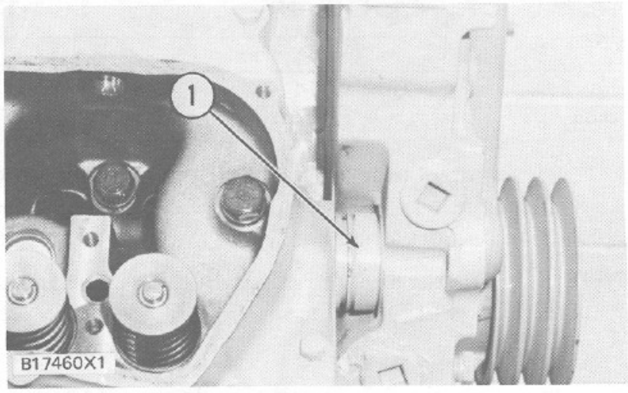
a) remove exhaust manifold

b) remove air inlet manifold

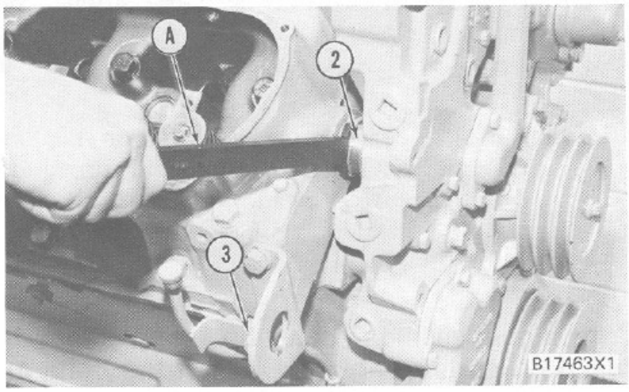
c) remove valve covers

d) remove fuel injection lines

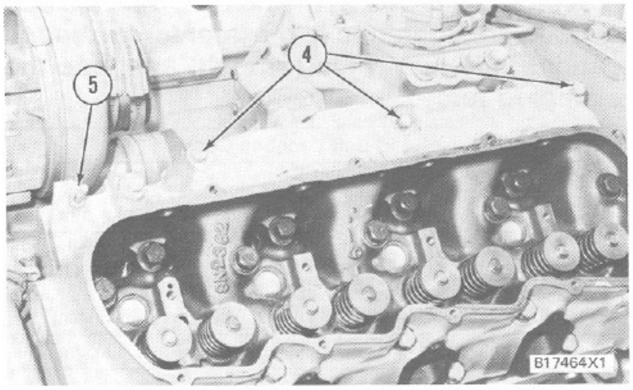
e) remove fuel injection nozzles



1. Remove the coolant from the cooling system.



2. Remove clamp (2) from water sleeves (1) in each cylinder head. Push the water sleeves into the timing gear cover with tool (A) and a screwdriver.

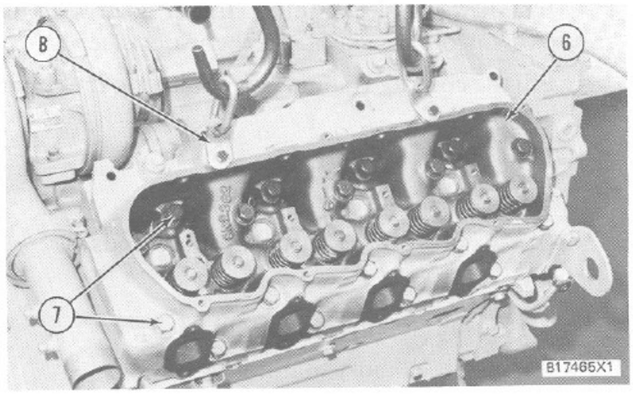


3. Remove bolt (3) from the bracket on the dipstick tube.

4. Remove bolts (4) and stud (5) from the heads.

NOTICE

Make sure the fuel injection nozzles are removed before the cylinder heads are removed. The fuel injection nozzles go through the cylinder heads and the nozzle tips can be broken off if the nozzles are not removed from the heads.



5. Install tooling (B) and fasten a hoist. Remove bolts (7), cylinder head (6) and the gasket. The weight of the cylinder head is 54 kg (120 lb.).

CYLINDER HEADS

INSTALL CYLINDER HEADS 1101-12

Tools Needed		A	B
6V7860	Water Sleeve Tool	1	
5P9736	Link Bracket		2

1. Clean the contact surfaces of the cylinder head and cylinder block. Make sure the surfaces are clean and dry. Install a new cylinder head gasket.

NOTE: Clean the bore in the cylinder head for the water sleeves. Put oil on the seals on the water sleeves.

2. Install tooling (B) in the cylinder head. Fasten a hoist and put the cylinder head in position on the cylinder block.

3. Put 6V4876 Molykote Lubricant on the bolt threads and install the bolts that hold the cylinder head in their correct location. Tighten the bolts in the cylinder head according to the HEAD BOLT TORQUE CHART.

NOTICE

The higher cylinder head bolt torque may be used on earlier engines ONLY if the bolts are replaced with the later higher strength bolts (seven dash marks on the bolt head). If the earlier bolts are tightened to the later torque specification, they may yield (stretch) and lose their clamping force.

Head Bolt Location Chart	
Location	**Length**
5, 2, 4, 10	5.25 in. (133.4 mm)
19, 20, 21	5.0 (127.0 mm)
16, 14, 12, 17	3.0 (76.2 mm)
7, 9, 3, 1, 6, 8	4.75 in. (120.6 mm)
18, 11, 13, 15	2.25 in. (57.2 mm)
22	Stud

4. Install water sleeve into cylinder head with tool (A). Install the clamp on the water sleeves.

5. Fill the cooling system with coolant to the correct level.

end by:

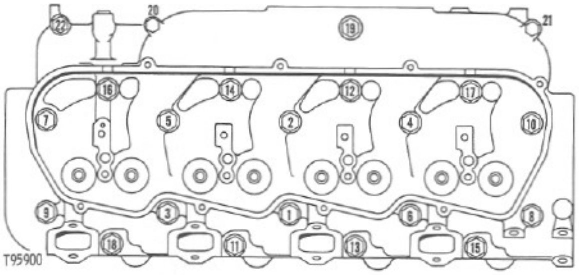
a) install fuel injection nozzles

b) install rocker shafts and push rods

c) install valve covers

d) install air inlet manifold

e) install exhaust manifold



Head Bolt Torque Chart		
Tightening Procedure	**Earlier Bolts (with six dash marks)[1]**	**Later Bolts (with seven dash marks)[1]**
Step 1. Tighten bolts 1 thru 18 in number sequence to:	130 ± 7 N.m (95 ± 5 lb.ft.)	150 ± 7 N.m (110 ± 5 lb.ft.)
Step 2. Loosen bolts 1 thru 18 until the washers can be turned freely.		
Step 3. Tighten bolts 1 thru 18 in number sequence to:	80 ± 14 N.m (60 ± 10 lb.ft.)	80 ± 14 N.m (60 ± 10 lb.ft.)
Step 4: Tighten bolts 1 thru 18 in number sequence to:	130 ± 7 N.m (95 ± 5 lb.ft.)	150 ± 7 N.m (110 ± 5 lb.ft.)
Step 5: Again tighten bolts 1 thru 10 in number sequence to:	130 ± 7 N.m (95 ± 5 lb.ft.)	165 ± 7 N.m (120 ± 5 lb.ft.)
Step 6. Tighten bolts 19 thru 22 in number sequence to:	43 ± 7 N.m (32 ± 5 lb.ft.)	43 ± 7 N.m (32 ± 5 lb.ft.)

[1] See Illustration 1 for identification of EARLIER and LATER bolts.

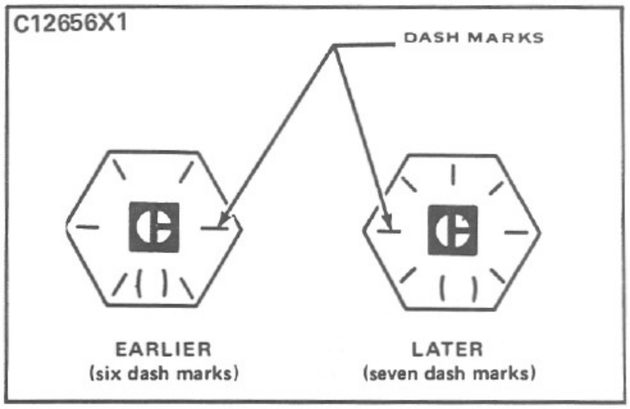


Illustration 1. Bolt head identification.

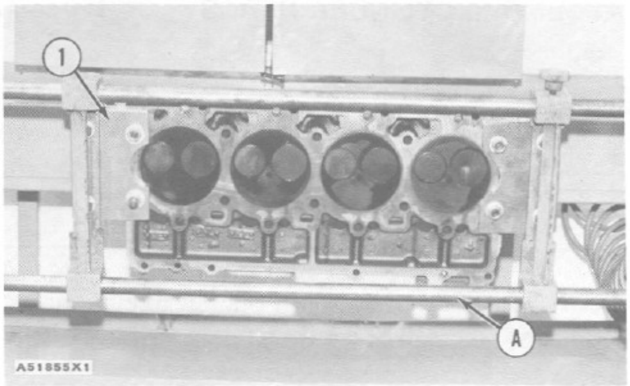
CYLINDER HEADS

DISASSEMBLE CYLINDER HEADS 1101—15

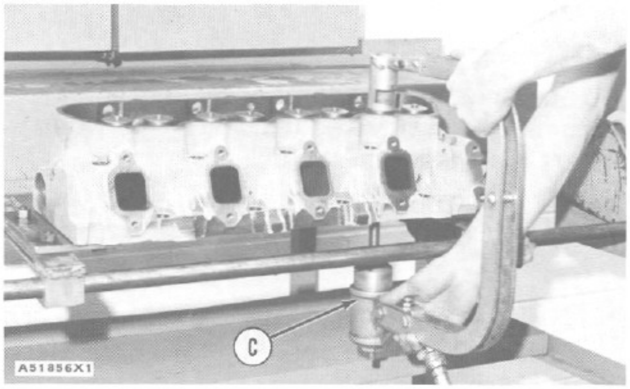
	Tools Needed	A	B	C	D
FT806	Cylinder Head Stand	1			
FT967	Adapter Plate	2			
8S2263	Valve Spring Tester		1		
5S1330	Valve Spring Compressor			1	
8S7170	Valve Seat Insert Puller Group				1

start by:

a) remove cylinder heads



1. Fasten a hoist and put the cylinder head in position on tool (A). Use adapter plates (1) from tooling (A) to hold the head in place.

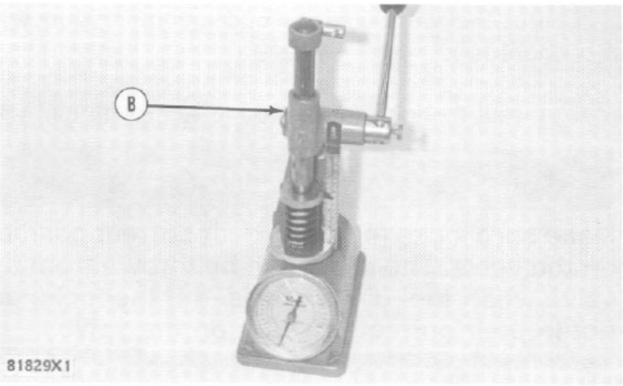


2. Put the valve springs under compression with tool (C).

3. Remove the locks from the valves.

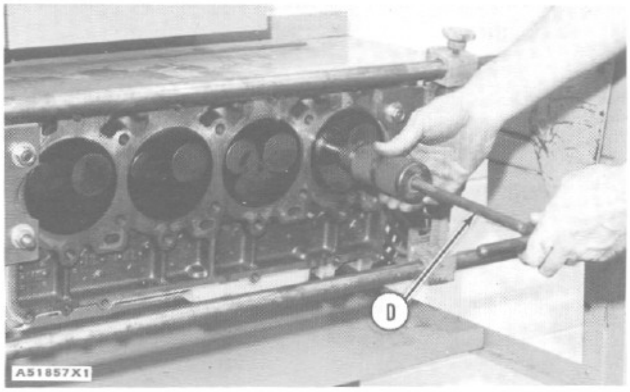
NOTE: Earlier engines have an inner valve spring. Later engines have only one valve spring and a spacer instead of inner spring.

4. Remove tool (C), retainer, spring, washer and valve from the cylinder head. Put identification on the valve as to its location in the cylinder head.



5. Check the valve spring force with tool (B). For the correct spring force, see the subject VALVES in SPECIFICATIONS.

6. Do Steps 2 through 5 for the remainder of the valves.



7. Remove the valve seat inserts with tooling (D).

NOTE: The valve guides are part of the cylinder head. Measure the bore in each valve guide 19.0 mm (.75 in.) from the outside edge on both ends of each valve guide. The bore must be 9.512 ± 0.013 mm (.3745 ± .0005 in.). The maximum permissible bore is 9.550 mm (.3760 in.). Valve guides worn more than the maximum specification can be made to the original size by knurling. To knurl the valve guides, see the topic CYLINDER HEAD AND VALVE COMPONENTS in the RECONDITIONING PROCEDURES.

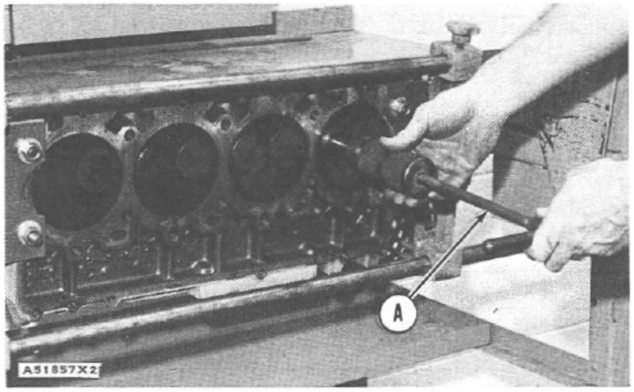
CYLINDER HEADS

ASSEMBLE CYLINDER HEADS 1101—16

Tools Needed		A	B	C
8S7170	Valve Seat Insert Puller Group	1		
5S1322	Valve Keeper Inserter		1	
5P1330	Valve Spring Compressor			1

1. Clean and remove burrs and all foreign material from the valve seat bores.

2. Lower the temperature of the valve seat inserts and install them with tooling (A).

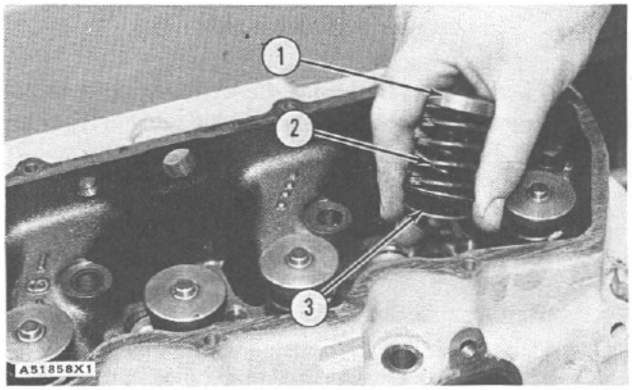


NOTICE

Do not make the diameter of the extractor (part of tooling A) in valve seat insert larger when the insert is installed in the cylinder head.

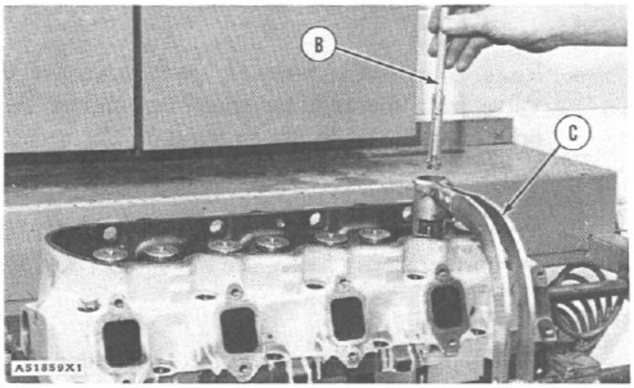
3. Grind the valve inserts according to the dimensions given in SPECIFICATIONS.

4. Put clean engine oil on the valve stem. Install the valve, washer (3), springs (2) and retainer (1) in the cylinder head.



5. Put the valve springs under compression with tool (C).

6. Install the locks on the valve stem with tool (B).



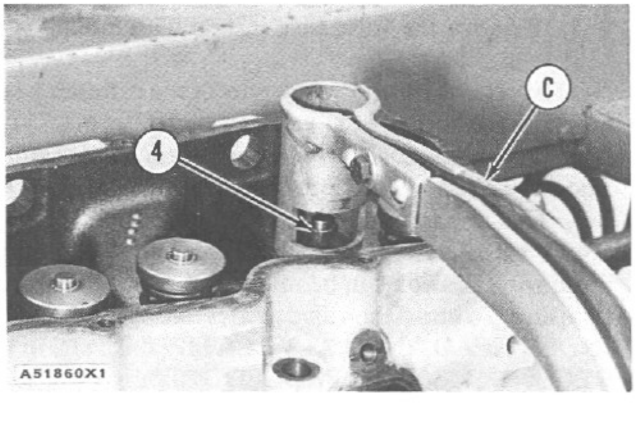
⚠ WARNING

Make sure locks (4) are in their correct position on the valve. The locks can be thrown from the valve when tool (C) is released if the locks are not in their correct position on the valve.

7. Remove tool (C) and hit the valve with a rubber hammer to be sure the locks are in their correct position.

8. Do Steps 4 through 7 for the remainder of the valves.

end by:
a) install cylinder heads



PISTON COOLING ORIFICES

REMOVE PISTON COOLING ORIFICES 1307-10

	Tools Needed	A
FT1542	Driver Orifice	1

start by:
a) remove crankshaft and gear

NOTICE

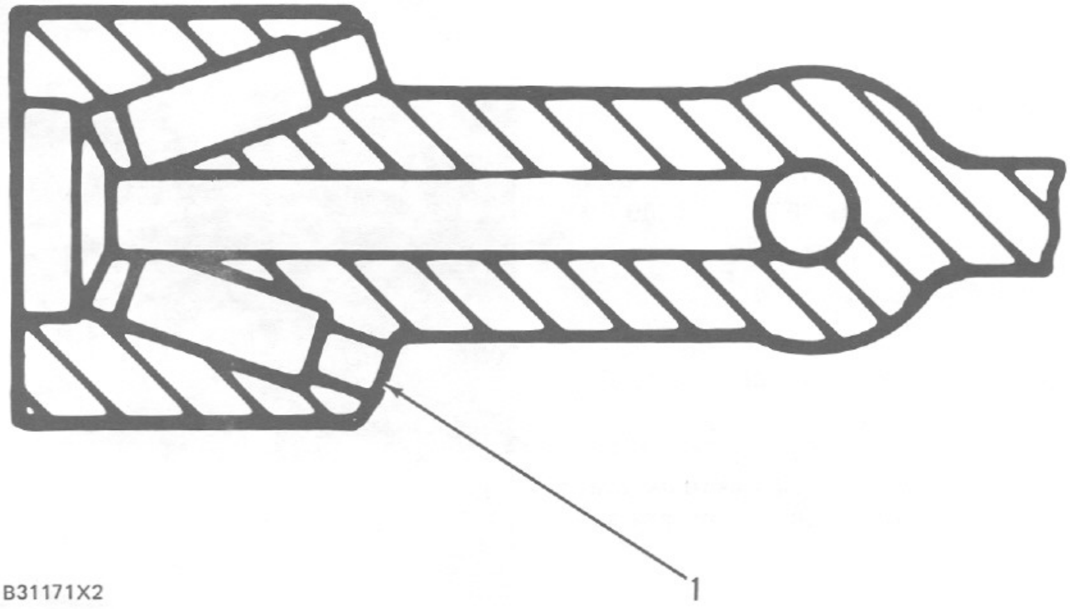
There are holes in the bores for the main bearing between the cylinders for piston cooling orifices. These holes must have orifices or plugs installed or low oil pressure will be the result. If the base for the oil cooler is 357.1 mm (14.06 in.) long, the engine has piston cooling orifices installed. If the base for the oil cooler is 268.2 mm (10.56 in.) long, the engine has plugs installed.

NOTE: A replacement of the piston cooling orifices is necessary only if they are damaged. Normally it will only be necessary to be sure the orifices are clean.

1. Use a soft punch to remove orifices (1) from the cylinder block.

2. Use tool (A) to install the orifices in the main bearing bores until they are against the counterbore. Be sure the orifices are open after they are installed.

end by:
a) install crankshaft and gear



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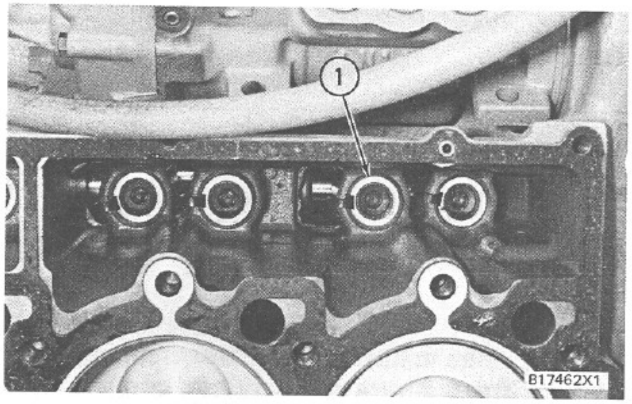
LIFTERS

REMOVE AND INSTALL LIFTERS (WITH ROLLERS) 1209-10

start by:
a) remove cylinder heads

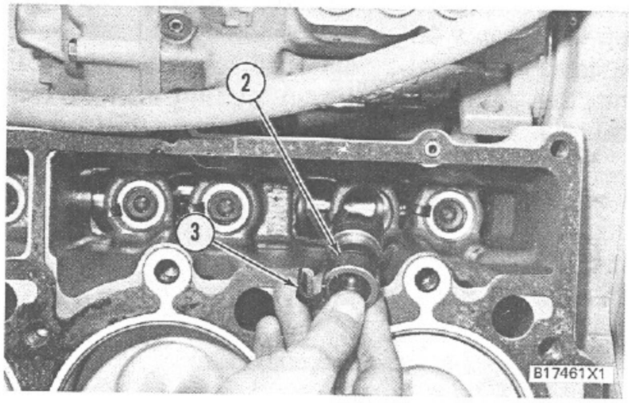
1. Remove valve lifters (1).



2. Put identification on each lifter as to its location in the engine for installation purposes.

3. Put the valve lifters in clean engine oil before installation.

4. Put lifter (2) and spring (3) in position so the tab on the spring is within an area 4.8 mm (.190 in.) either side of the centerline of the cam and valve lifter bores.



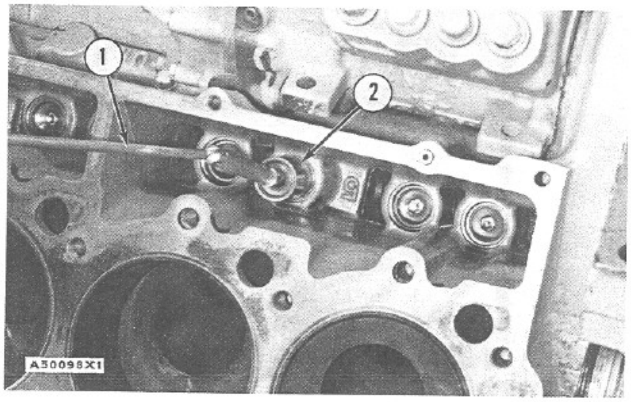
NOTE: If necessary turn the camshaft so lifters can be pushed into correct position.

end by:
a) install cylinder heads

REMOVE AND INSTALL LIFTERS 1209-10

start by:
a) remove cylinder heads

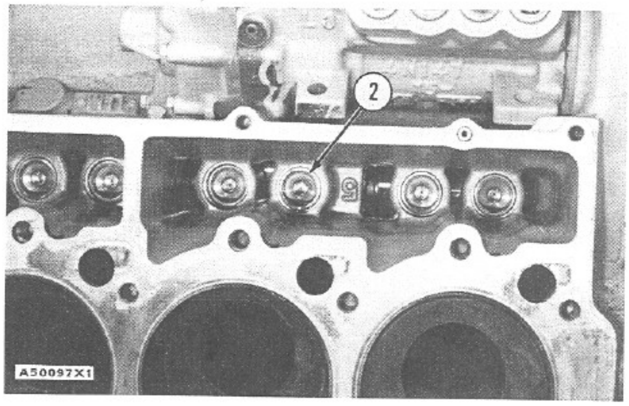
1. Remove valve lifters (2) with magnet (1).



2. Put identification on each lifter as to its location in the engine for installation purposes.

3. Put clean engine oil on the valve lifters and camshaft lobes.

4. Install the valve lifters (2) in their original positions in the cylinder block.



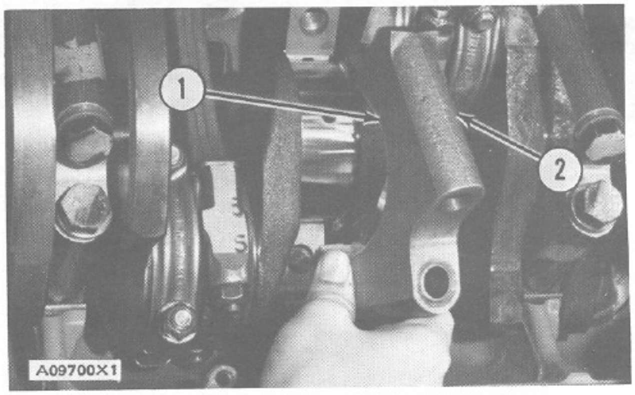
end by:
a) install cylinder heads

CRANKSHAFT MAIN BEARINGS

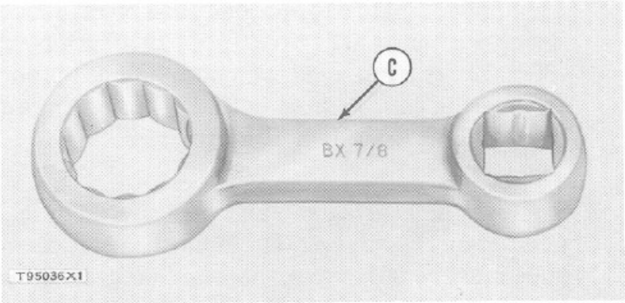
REMOVE AND INSTALL CRANKSHAFT MAIN BEARINGS 1203-10

	Tools Needed	A	B	C	D
2P5518	Bearing Tool	1			
	Plastigage		*		
8S5131	Adapter			1	
8S2328	Dial Test Indicator Group				1

start by:
a) remove oil pan



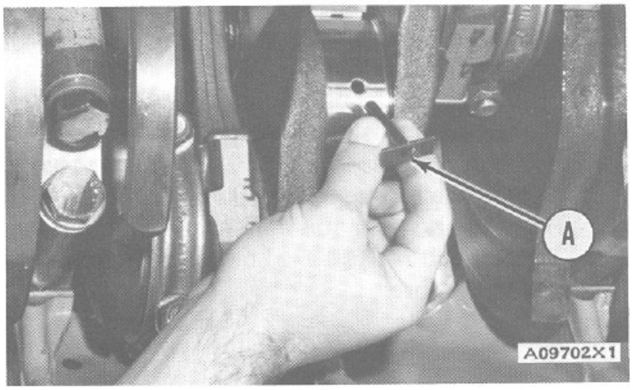
1. Check each main bearing cap for its location on the engine. Each cap has a number which gives the location of that cap. Make a note that the number on each cap is toward the front of the cylinder block.



2. Remove the bolts and washers that hold main bearing cap (2) in place. Remove the bearing cap and the lower half of the main bearing. Use tool (C) to remove the bolts that hold the No. 1 main bearing cap in position.

3. Remove bearing (1) from the bearing cap.

NOTE: No. 1 main does not have an oil hole for insertion of tool (A).

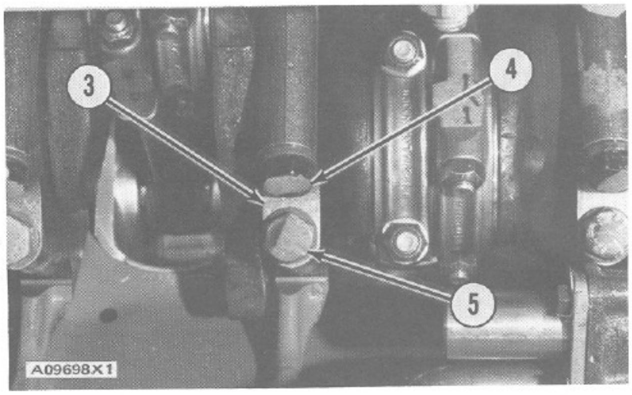


4. Turn the crankshaft until tool (A) can be installed in the oil hole in the crankshaft journal. Install tool (A). Turn the crankshaft in the direction which will push the upper main bearing out, tab end first.

NOTICE

If the crankshaft is turned in the wrong direction, the tab of the bearing will be pushed between the crankshaft and the cylinder blocks. This will cause damage to the crankshaft and block.

NOTE: Install the bearings dry when the clearance checks are made. Put clean engine oil on the bearings for final assembly.



5. Install the lower bearing in the bearing caps. Install upper bearings (bearing with the oil hole) in the cylinder block with tool (A).

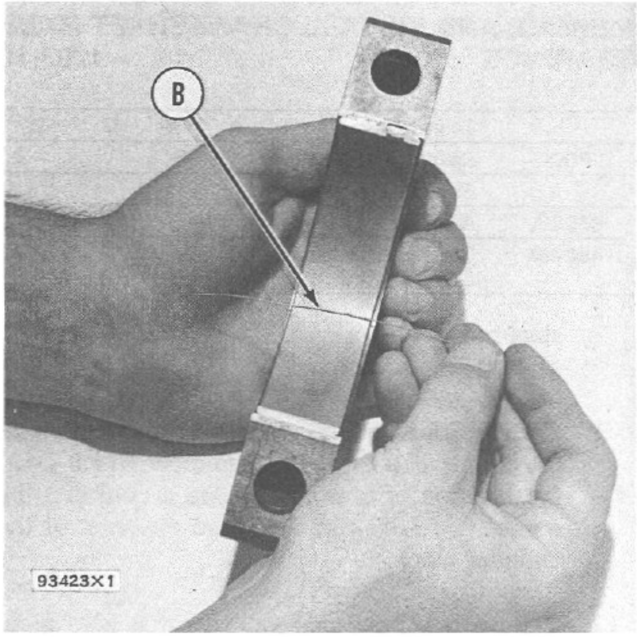
NOTICE

When bearing caps are installed, make sure the caps are installed with the part number toward the front of the engine and the number on the bottom of the cap is the same as the number on the camshaft side of the engine.

CRANKSHAFT MAIN BEARINGS

NOTE: When the bearing clearance is checked and the engine is in a vertical position, such as in the vehicle, the crankshaft will have to be lifted up and held against the upper halves of the main bearings to get a correct measurement with Plastigage (B). The Plastigage will not hold the weight of the crankshaft and give a correct indication. If the engine is in a horizontal position, such as on an engine stand, it is not necessary to hold the crankshaft up. Do not turn the crankshaft when Plastigage (B) is in position.

6. Check the bearing clearance with Plastigage (B) as follows:
   Put cap (3) in position and install the bolts. Tighten bolt (5) to a torque of 40 ± 4 N•m (30 ± 3 lb.ft.). Tighten bolt (4) to a torque of 40 ± 4 N•m (30 ± 3 lb.ft.). Put a mark on both bolt heads and the bearing cap. Tighten bolt (4) 120 ± 5° more. Tighten bolt (5) 120 ± 5° more.



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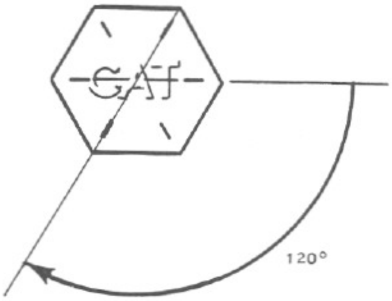
7. Remove the bearing cap and measure the thickness of the Plastigage. The main bearing clearance must be 0.076 to 0.168 mm (.0030 to .0066 in.). The maximum permissible clearance is 0.18 mm (.007 in.).



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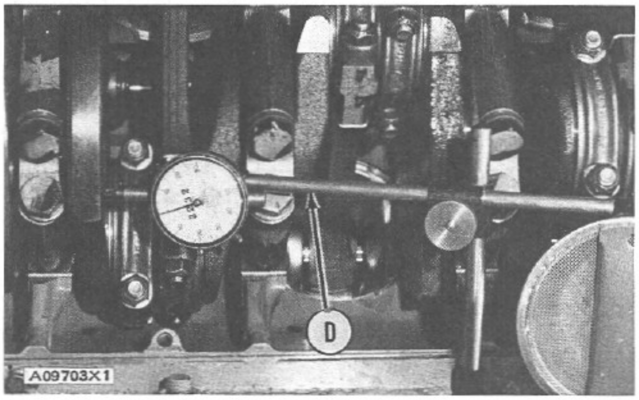
8. Put 2P2506 Thread Lubricant on the bolt threads and washers faces. Put clean engine oil on the lower half of the main bearing. Put the bearing cap and lower half of the main bearing in position on the engine. Install the bolts. Tighten bolt (5) to a torque of 40 ± 4 N•m (30 ± 3 lb.ft.). Tighten bolt (4) to a torque of 40 ± 4 N•m (30 ± 3 lb.ft.). Put a mark on both bolt heads and the cap. Tighten bolt (4) 120 ± 5° more. Tighten bolt (5) 120 ± 5° more.

9. Do Steps 1 through 8 for the remainder of the bearings.

NOTE: When a replacement of the thrust plates on No. 3 main bearing is made, install the thrust plates with the identification "BLOCK SIDE" next to the block.



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10. Check the crankshaft end play with tooling (D). The end play is controlled by the thrust bearing on No. 4 main bearing. The end play with new bearings must be 0.08 to 0.25 mm (.003 to .010 in.). The maximum permissible end play with used bearing is 0.36 mm (.014 in.).

    end by:
    a) install oil pan

CONNECTING ROD BEARINGS

REMOVE AND INSTALL CONNECTING ROD BEARINGS 1219-10

Tools Needed	A
Plastigage	*

start by:
a) remove oil pan

1. Turn the crankshaft until two pistons are at bottom center. Remove connecting rod caps (1) from the two connecting rods. Remove the lower half of the bearings from the caps.
2. Push the connecting rods away from the crankshaft and remove the upper half of the bearings.

NOTICE

Be careful not to damage the crankshaft journals. Do not turn the crankshaft while any of the connecting rod caps are removed.

NOTE: Install the bearings dry when the clearance checks are made. Put clean engine oil on the bearings for final assembly.

3. Clean the surfaces where the bearings fit. Install the upper half of the bearing in the connecting rod. Pull the connecting rod slowly on to the crankshaft.
4. Install lower half of the bearing in the cap.

NOTICE

When the connecting rod caps are installed, make sure that the numbers on the side of the caps are next to and respective with the number on the side of the connecting rods.

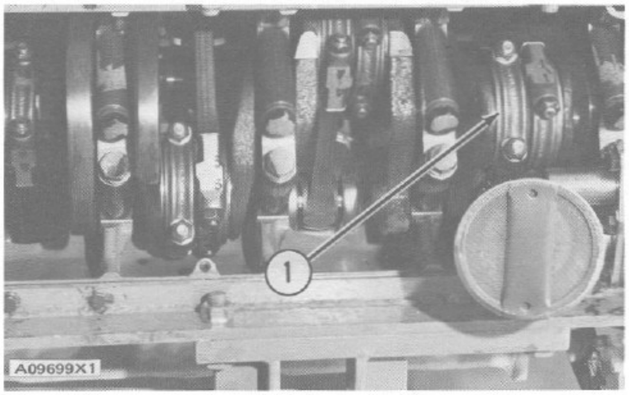
5. Check the bearing clearance with Plastigage (A). Put Plastigage (A) on the bearing.
6. Put 2P2506 Thread Lubricant on the threads of the rod bolts and seat surfaces of the nuts.

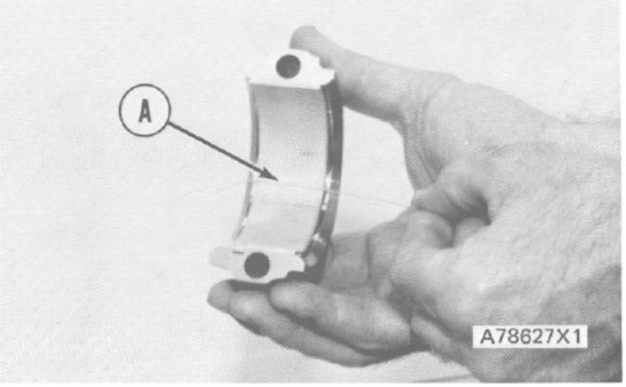
NOTICE

Do not use an impact wrench to tighten the nuts the additional 60 ± 5°.

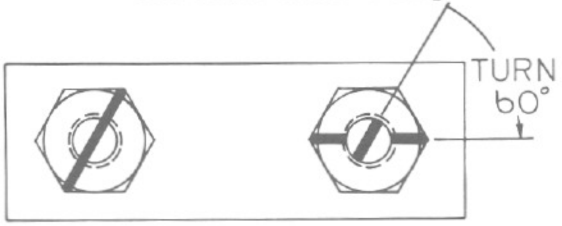
NOTE: Do not turn the crankshaft when Plastigage (A) is in position.

7. Put caps (1) in position on the connecting rods and install the nuts. Tighten the nuts to a torque of 40 ± 4 N•m (30 ± 3 lb.ft.). Put a mark on each nut and the end of each bolt. Tighten the nuts 60 ± 5° more.
8. Remove the cap. Measure the thickness of Plastigage (A). The rod bearing clearance must be 0.053 to 0.140 mm (.0021 to .0055 in.). The maximum permissible clearance is 0.15 mm (.006 in.).
9. Put the caps in position on the connecting rods and install the nuts. Tighten the nuts to a torque of 40 ± 4 N•m (30 ± 3 lb.ft.). Put a mark on each nut and the end of each bolt. Tighten the nuts 60 ± 5° more.





TYPICAL EXAMPLE



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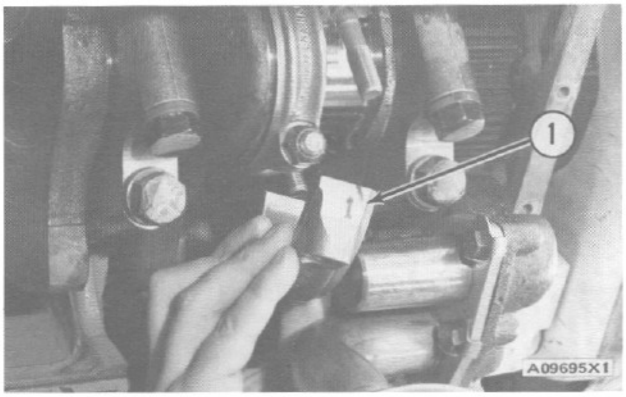


10. Do Steps 1 through 9 again for other bearings.

end by:
a) install oil pan

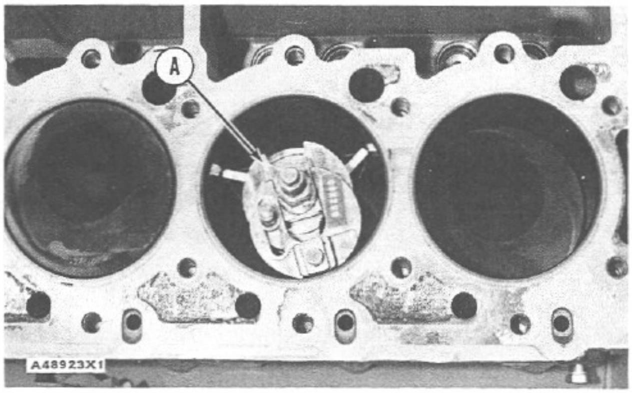
PISTONS

REMOVE PISTONS 1214-11

	Tools Needed	A
8S2269	Ridge Reamer	1

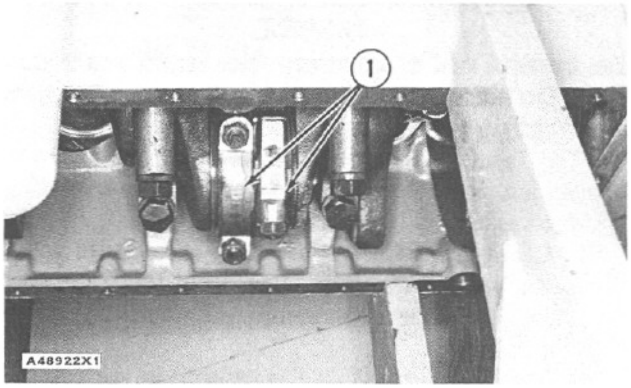
start by:
a) remove cylinder heads
b) remove oil pan

1. Remove the carbon from the top inside surface of the cylinders with tool (A).



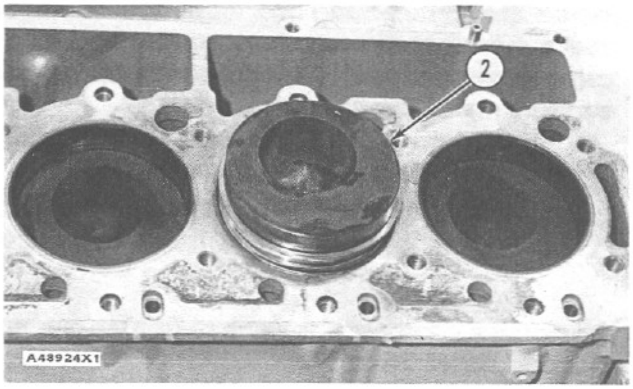
2. Turn the crankshaft until two pistons are at bottom center.

3. Remove connecting rod caps (1) from the two connecting rods. Put pieces of rubber hose or tape on the threads of the connecting rod bolts as protection for the crankshaft.



4. Push the pistons and connecting rods away from the crankshaft until the piston rings are above the cylinder block.

5. Remove the two pistons (2) and the connecting rods. Keep each connecting rod cap with its respective connecting rod and piston. Put identification on each connecting rod as to its location for use at installation.



NOTICE

Do not turn the crankshaft while any of the connecting rods are in the engine without the caps installed.

6. Do Steps 2 through 5 for the remainder of the pistons.

PISTONS

INSTALL PISTONS 1214-12

	Tools Needed	A	B
5P3524	Ring Compressor	1	
	Plastigage		*

NOTICE

Two different pistons are used in 3208 Truck Engines. One piston has a crater volume of 50.4 ± 1.3 cm³ (3.08 ± .07 in.³), and the other piston has a crater volume of 58.8 ± 1.2 cm³ (3.59 ± .07 in.³). Check the part number stamped on the top of the piston and refer to the parts book to be sure the correct replacement piston is used. The correct piston must be installed in the engine. If the wrong piston is installed, much damage to the engine will be the result.

1. Put clean engine oil on the piston rings, connecting rod bearings, cylinder walls and crankshaft bearing journals.
2. Turn the crankshaft until the bearing journal for the pistons to be installed is at bottom center.
3. Make sure the piston ring gaps are at least 120° apart on the piston.
4. Use tool (A) and install the piston in position in the same cylinder bore from which it was removed. The hole (crater) in the top of the piston must be toward (nearest) the center of the engine.

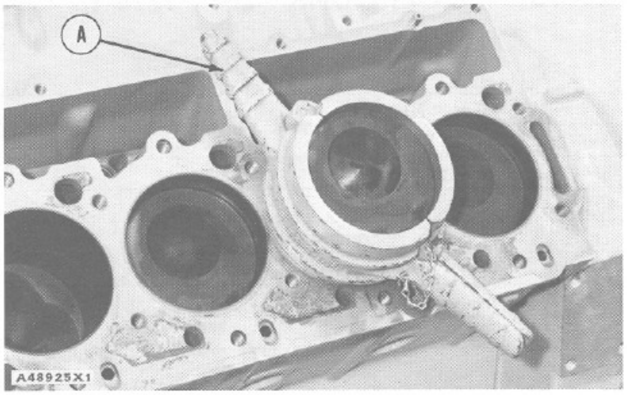
NOTE: For more detail about the installation of connecting rod bearings, see REMOVE AND INSTALL CONNECTING ROD BEARINGS.

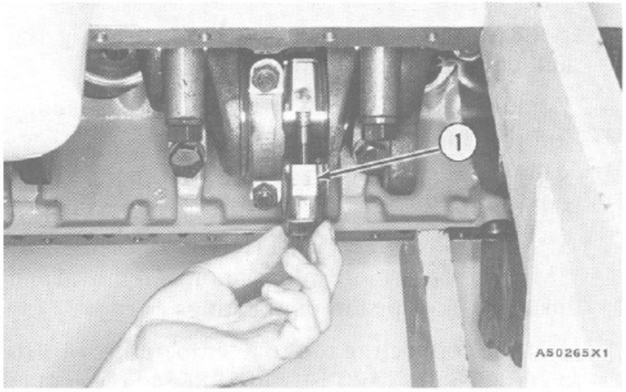
5. Check the bearing clearances with tool (B).
6. Put 2P2506 Thread Lubricant on the threads of the bolts and contact surfaces of the nuts for the connecting rod caps.

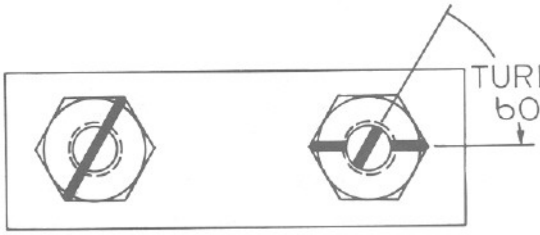
NOTICE

When the connecting rod caps are installed, make sure that the number on the side of the cap is next to and respective with the number on the side of the connecting rod.

7. Put the cap (1) in position on the connecting rod and install the nuts. Tighten the nuts to a torque of 40 ± 4 N•m (30 ± 3 lb.ft.). Put a mark on each nut and the end of each bolt. Tighten the nuts 60 ± 5° more.







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8. Check the side clearance between two connecting rods on the same crankshaft journal. Clearance must be 0.08 to 0.84 mm (.003 to .033 in.) for new rods.
9. Do Steps 1 through 8 for the remainder of the pistons.

end by:
a) install cylinder heads
b) install oil pan

PISTONS

DISASSEMBLE PISTONS 1214-15

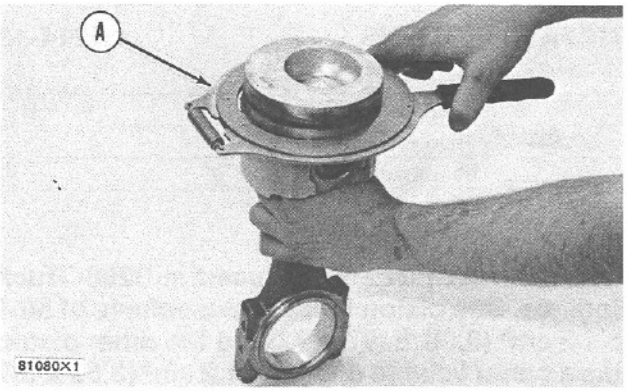
	Tools Needed	A	B
5F9059	Ring Expander	1	
5P8639	Press Group		1
8F24	Hose Assembly		1
1P2375	Coupler Assembly		1
1P2376	Coupler Assembly		1
5P8719	Hand Pump		1
5P8652	Tool Group		1

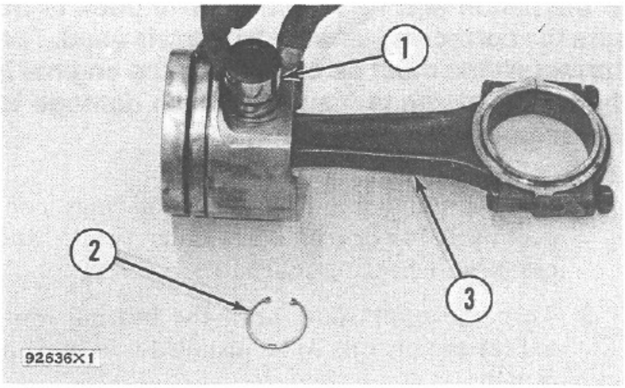
start by:
a) remove pistons

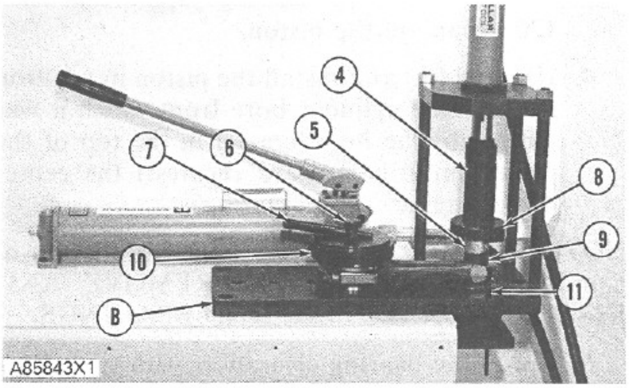
1. Remove the rings from the piston with tool (A).
2. Remove the bearings from the connecting rod and connecting rod cap.
3. Remove snap rings (2), pin (1) and connecting rod (3) from the piston.
4. See USE OF PISTON PIN BEARING REMOVAL AND INSTALLATION TOOLS, SPECIAL INSTRUCTIONS, Form No. SMHS7295 for more information of removal and installation of piston pin bearings.
5. **Heat the connecting rod to a temperature of 176 to 260°C (350 to 500°F). Put 5P8654 Spacer (11) in the base plate. Put the connecting rod on the base plate of tooling (B).**
6. Put the connecting rod piston pin bearing end in the center of the port assembly of tooling (B). Install pin (7) in the center of the bore for the connecting rod bearings.
7. Install 5P8653 Adapter (9). Put the hole in the adapter in alignment with the hole in the base plate of tooling (B).
8. Install clamp bar (10) and clamp pin (6).
9. Install new piston pin bearing (5) on adapter (9).

NOTE: The old bearing is pushed out by tooling (B) as the new bearing is installed.

10. Put 5P8645 Adapter (8) in position as shown with the taper side down. The piston pin bearing joint must be in alignment with the hole in adapter (9) and the base plate of tooling (B).
11. Put pusher (4) on adapter (8).
12. Use tooling (B) to push the new piston pin bearing into the connecting rod until adapter (8) of tooling (B) makes full contact with the connecting rod surface.







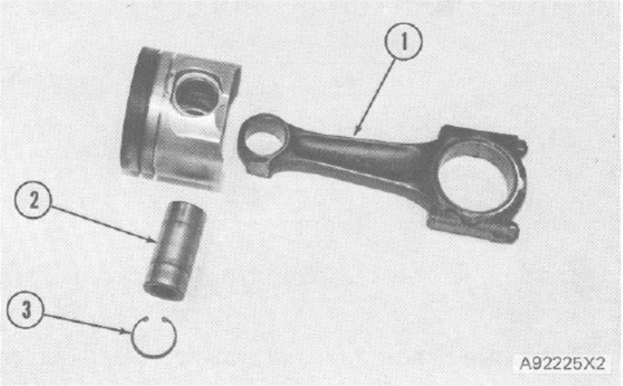
13. Remove the connecting rod and the old piston pin bearing from tooling (B).
14. **Check the piston pin bearing bore diameter after the bearing is installed. The correct dimension is 38.125 ± 0.008 mm (1.5010 ± .0003 in.).**

PISTONS

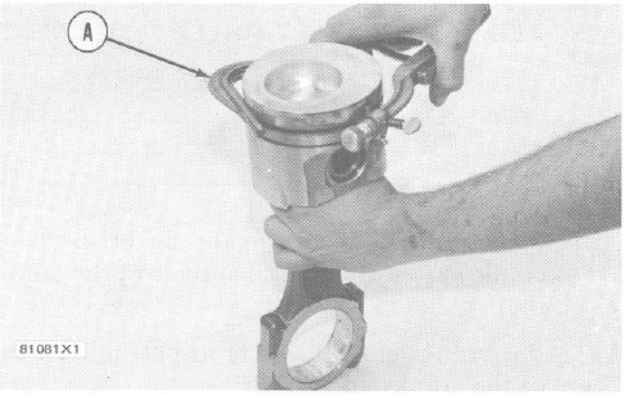
ASSEMBLE PISTONS 1214-16

	Tools Needed	A	B
8S2304	Piston Ring Groove Cleaner	1	
5F9059	Ring Expander		1

1. Install connecting rod (1) in the piston with the boss on small end of connecting rod on the same side as the hole (crater) in top of the piston.
2. Install piston pin (2) and snap ring (3).



3. When old pistons are to be used, clean the piston grooves with tool (A).



4. Install the spring for the oil ring. Install the oil ring with tool (B). The gap in the ring must be approximately 180° from the oil ring spring connections.
5. Install the compression ring with tool (B). The side of the ring that has the identification "TOP" must be toward the top of the piston. The gaps in the rings must be approximately 120° apart.

NOTE: Compression rings that do not have identification must be installed with the edge that has the bevel toward the top edge that has the bevel toward the top of the piston.

6. Install connecting rod bearings.

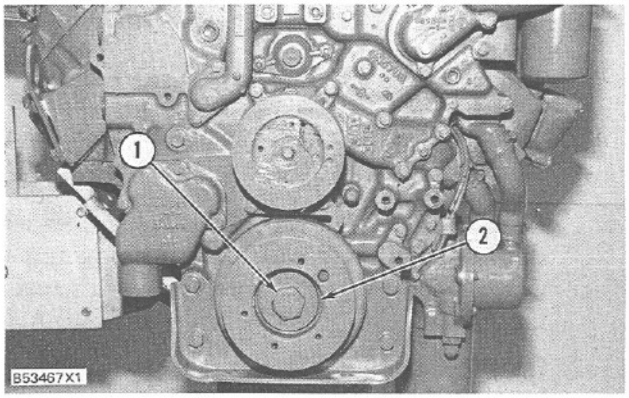
end by:
a) install pistons

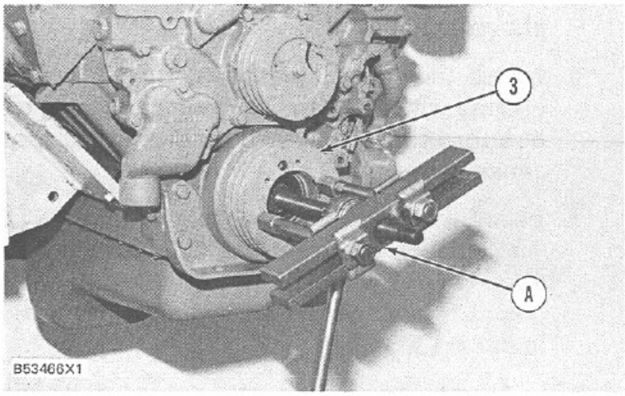
CRANKSHAFT PULLEY

REMOVE CRANKSHAFT PULLEY 1205-11

	Tools Needed	A
8B7548	Puller Assembly	1
8B7557	Adapter	2
8H684	Ratchet Box Wrench	1
8B7561	Step Plate	1

1. Remove the vee belts from the front of the engine.
2. Remove bolt (1) and washer (2) from the crankshaft.
3. Use tooling (A) to pull the crankshaft pulley (3) from the crankshaft.

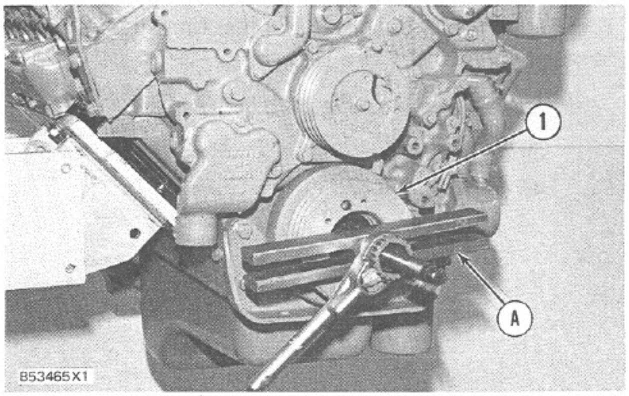




INSTALL CRANKSHAFT PULLEY 1205-12

	Tools Needed	A
8B7548	Puller Assembly (without legs)	1
8H684	Ratchet Box Wrench	1

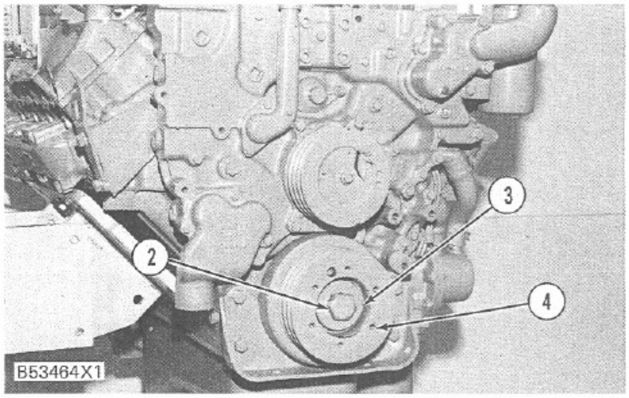
1. Put clean engine oil on the lip of the front crankshaft seal and seal surface of the crankshaft pulley.
2. Put crankshaft pulley (1) in position on end of the crankshaft.
3. Install the screw of tooling (A) in the end of the crankshaft. Put crossbar of tooling (A) on screw and against the pulley. Use tooling (A) to push the pulley on to crankshaft until it makes contact with the crankshaft gear inside timing gear housing. Remove tooling (A).



4. Install washer (3) and bolt (2) in the end of the crankshaft. Tigthen the bolt to a torque of 624 ± 80 N•m (460 ± 60 lb.ft.).

NOTE: When a front power take-off is used, tighten bolt (2) to a torque of 950 ± 50 N•m (700 ± 37 lb.ft.). Tighten bolts [for holes (4)] to a torque of 55 ± 7 N•m (40 ± 5 lb.ft.).

5. Install the vee belts and make an adjustment to the belt tension. See the V-BELT TENSION CHART in the SPECIFICATIONS.



TIMING GEAR COVER AND OIL PUMP

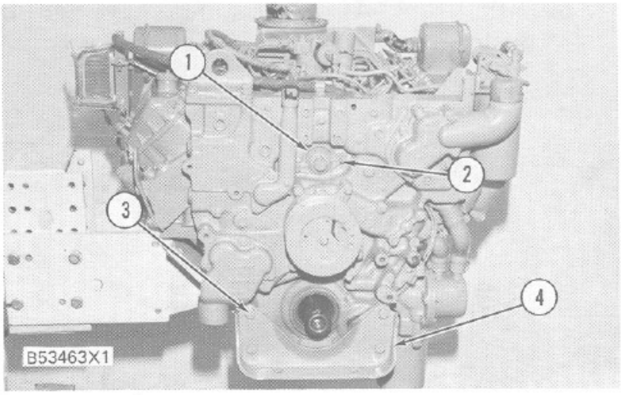
REMOVE TIMING GEAR COVER AND OIL PUMP 1166 & 1304-11

	Tools Needed	A	B
6V116	Water Sleeve Tool	1	
5P9736	Link Bracket		2

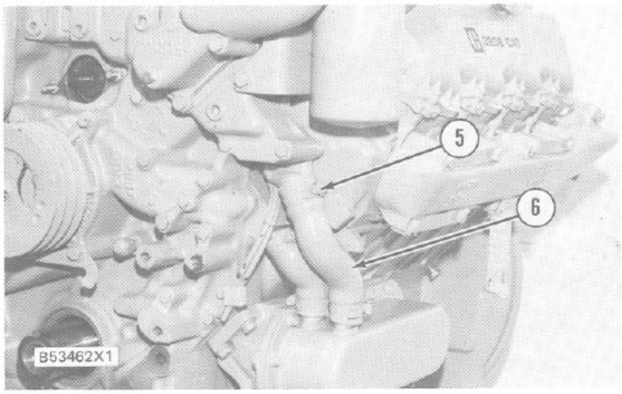
start by:

a) remove oil pan

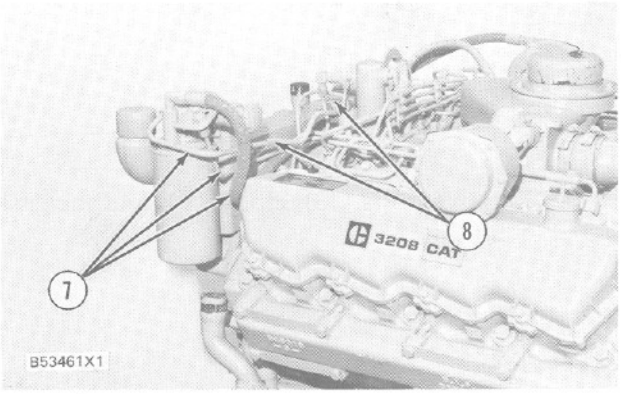
b) remove crankshaft pulley



1. Remove nuts (2) and tachometer drive cover (1).

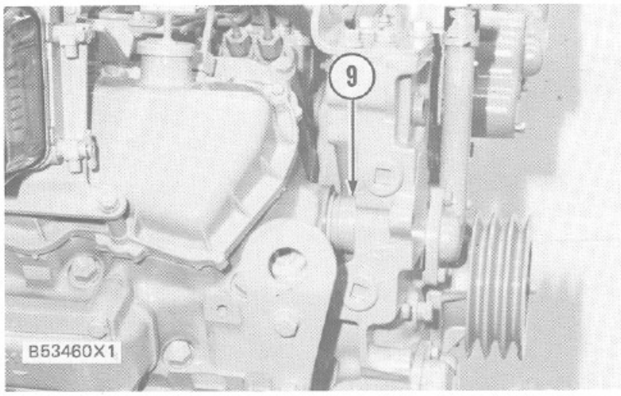


2. Remove bolts (3) and front support (4).



3. Loosen clamp (5) and disconnect hose (6) from the timing gear cover.

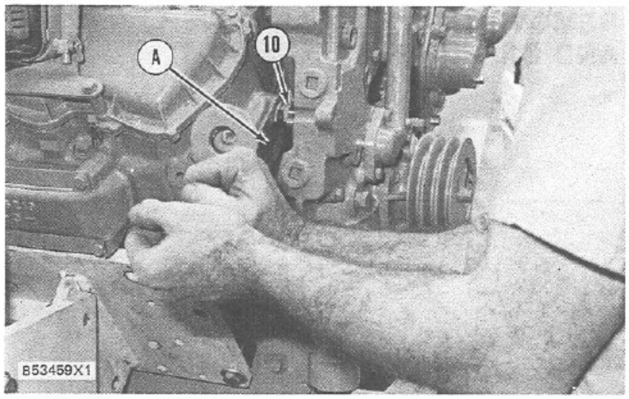
4. Remove clips (8) and then disconnect three lines (7).



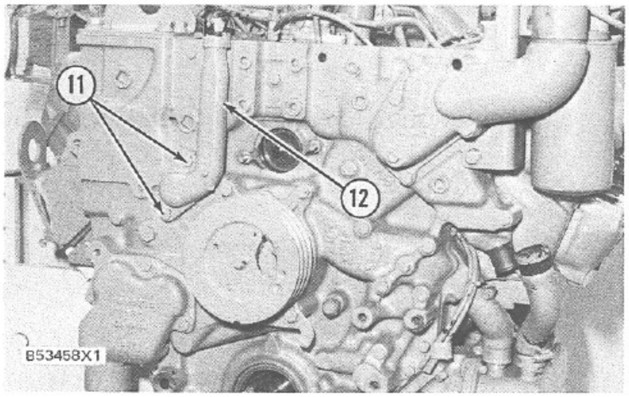
5. Remove clamp (9) from the water sleeve.

TIMING GEAR COVER AND OIL PUMP

6. Install tool (A) on the water sleeve and then push water sleeve (10) into the front cover.


A
10
B53459X1

7. Remove two bolts (11), connector (12) and the gasket behind it.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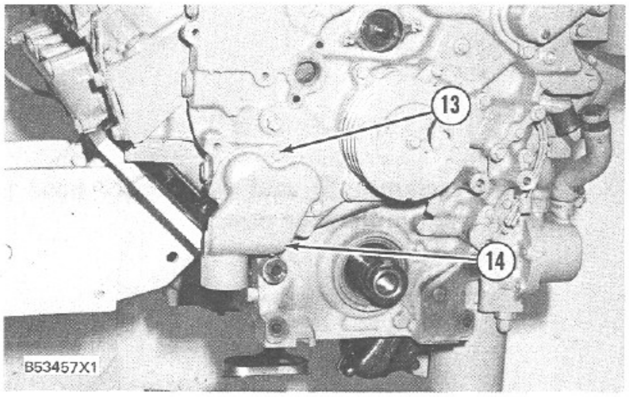
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14
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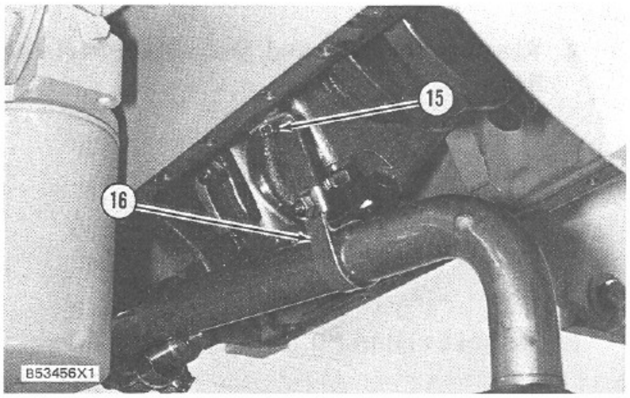
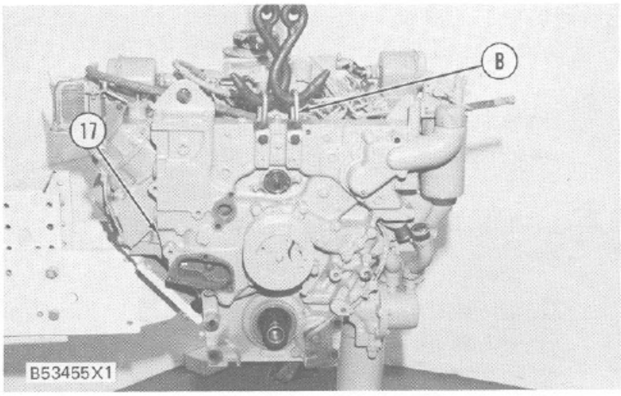
8. Remove bolts (13), elbow (14) and the gasket behind it.


15
16
B53456X1

9. Remove bolt (15) and then disconnect clamp (16) that holds the oil pump sump tube.

TIMING GEAR COVER AND OIL PUMP

10. Install tooling (B) in the front cover and then fasten a hoist. Remove all the bolts that hold timing gear cover to the cylinder block. Remove the cover (17) and oil pump. The weight of the timing gear cover and oil pump is 62 kg (136 lb.).



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NOTICE

Be extra careful not to cause damage to the crankshaft front seal during removal and installation of the timing gear cover.

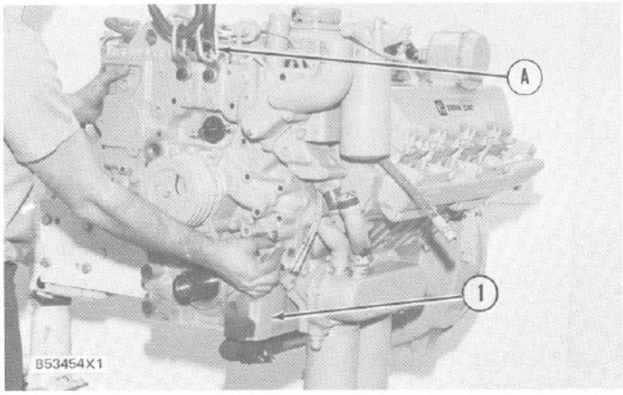
INSTALL TIMING GEAR COVER AND OIL PUMP 1166 & 1304-12

	Tools Needed	A	B
5P9736	Link Bracket	2	
6V116	Water Sleeve Tool		1

1. Clean the contact surfaces of the cylinder block and timing gear cover. Install the timing gear cover gasket on the cylinder block.

NOTE: Make sure the water sleeves are installed in the timing gear cover. Put oil on the seals on the water sleeves.

2. Install tooling (A) on timing gear cover (1).



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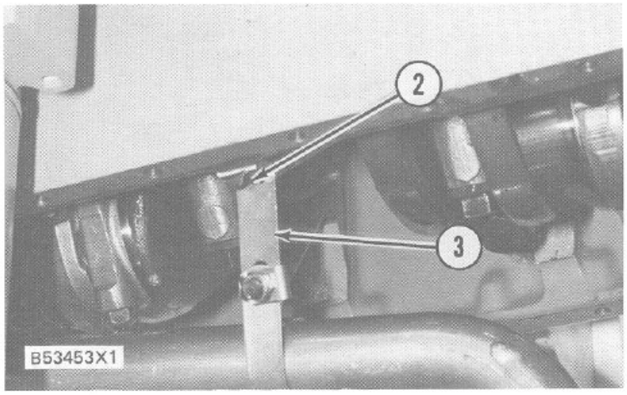
3. Put the cover in position and make an alignment of the dowels and their respective holes. Install the bolts that hold cover (1) to the cylinder block.

4. Connect clamp (3) that holds the oil pump sump tube. Install bolt (2).



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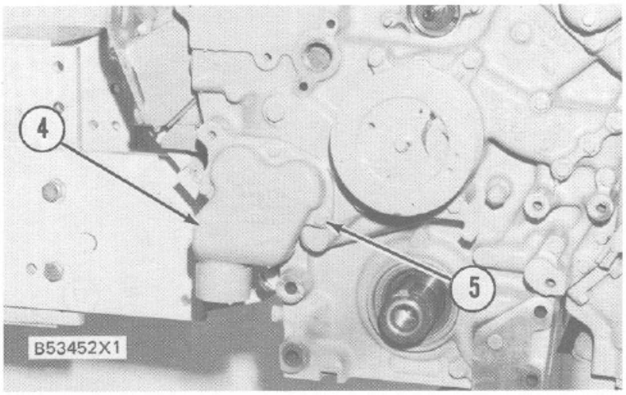
5. Install gasket and elbow (4) on the timing gear cover with the bolts (5) that hold it.



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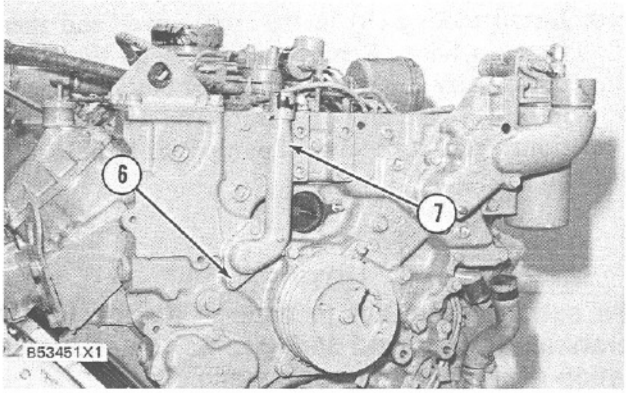
TIMING GEAR COVER AND OIL PUMP

6. Install gasket and connector (7) in the cover and install the bolts (6) that hold it.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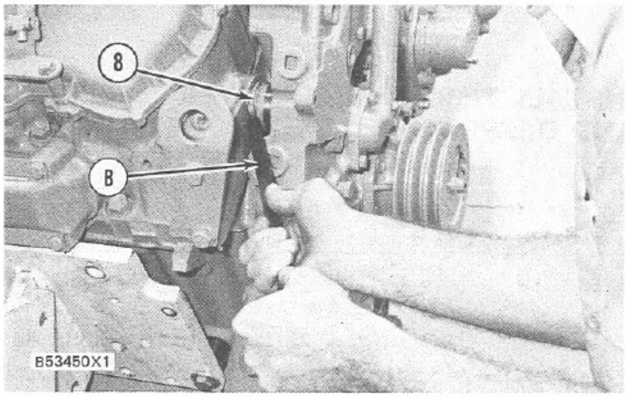
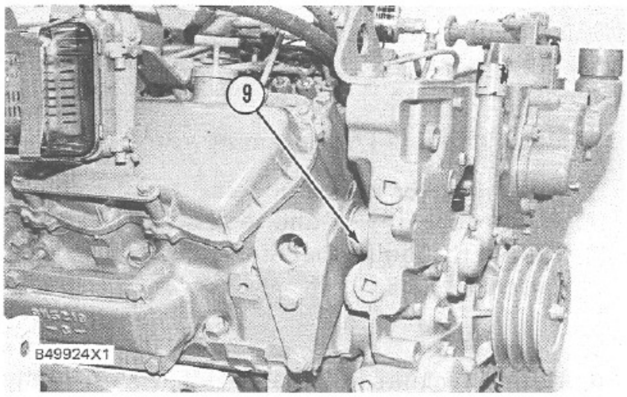
B53451X1

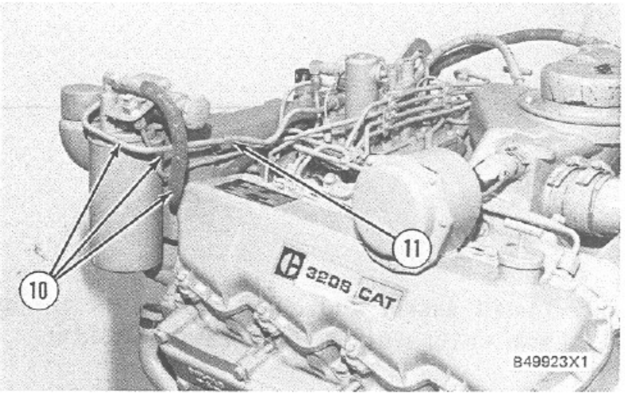
7. Install tool (B) on water sleeve (8), then push water sleeve into the cylinder block.


8
B
B53450X1

8. Install clamps (9) on the water sleeve.



9. Connect three lines (10) and install the clips (11) that hold them.


10
11
3208 CAT
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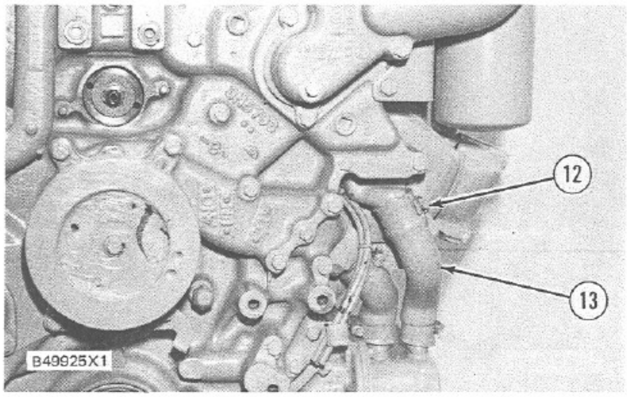
10. Install hose (13) on timing gear cover and install clamp (12).


12
13
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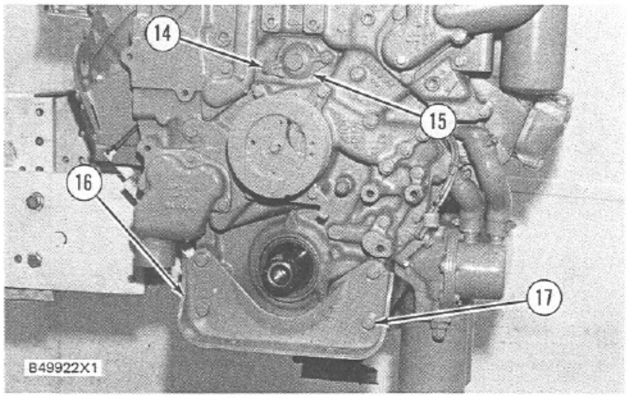
11. Put engine support (16) in position and install the bolts (17) that hold it.


14
15
16
17
B49922X1

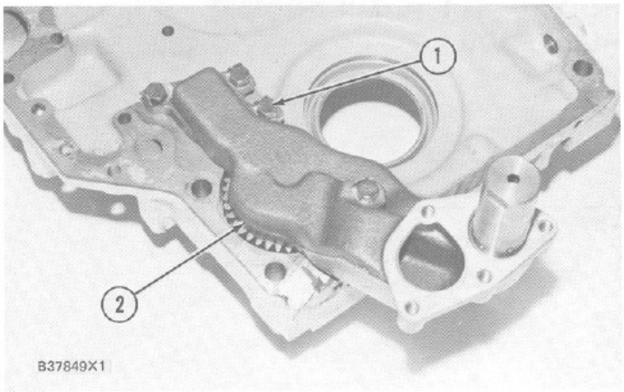
12. Put tachometer cover (15) in position and install the nuts (14) that hold it.

end by:
a) install crankshaft pulley
b) install oil pan

OIL PUMP AND RELIEF VALVE

REMOVE OIL PUMP AND RELIEF VALVE 1304 & 1315-11

start by:
a) remove timing gear cover and oil pump



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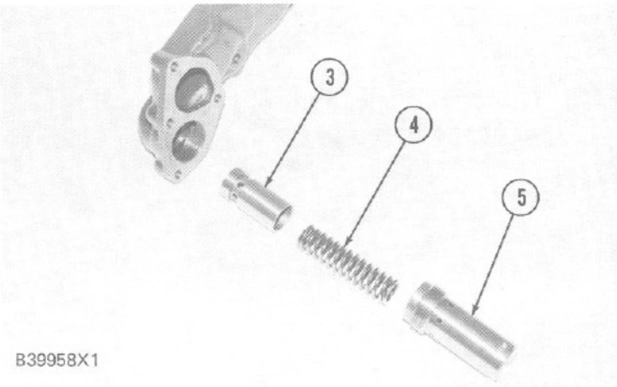
1. Bend the locks away from bolts (1) and remove the bolts. Remove cover (2) from the timing gear cover.



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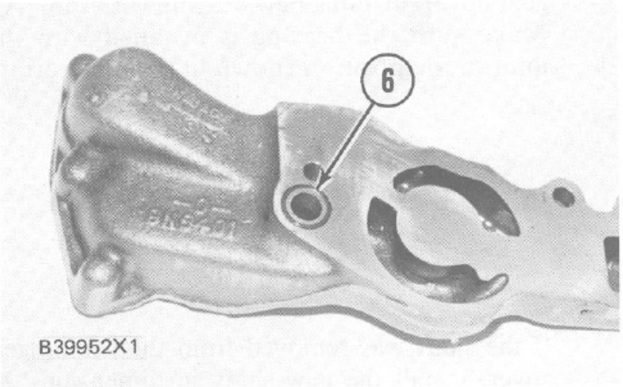
2. Remove guide (5), spring (4) and plunger (3) from the cover.



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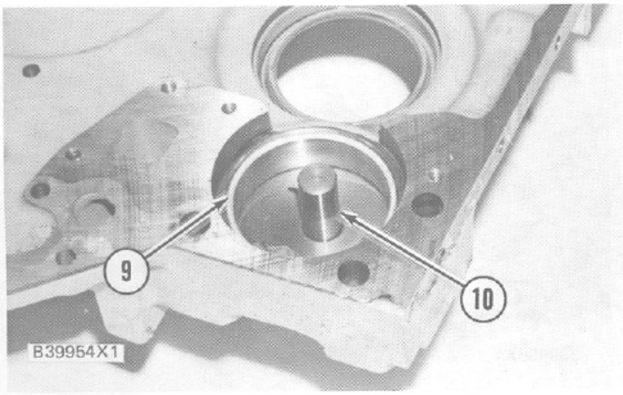
3. Remove O-ring seal (6) from the back of the cover.

4. Remove inner rotor (7) and outer rotor (8) from the timing gear cover.

5. Measure the inside diameter of bearing (9). The inside diameter must be 71.22 ± 0.05 mm (2.804 ± .002 in.). Remove bearing (9) only if a replacement is necessary. Remove shaft (10) if a replacement is necessary.



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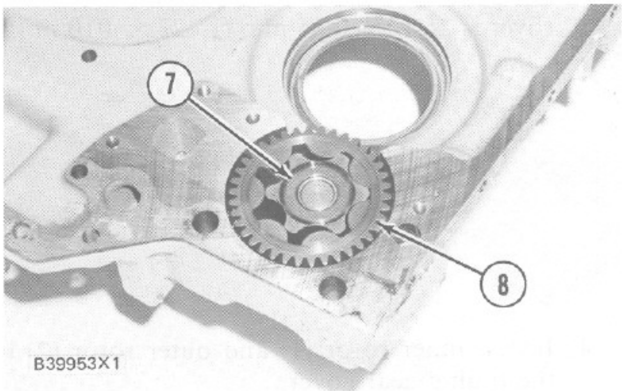

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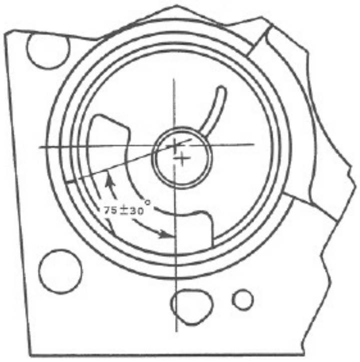
OIL PUMP AND RELIEF VALVE

INSTALL OIL PUMP AND RELIEF VALVE 1304 & 1315-12

	Tools Needed	A
8S2285	Driver Assembly	1



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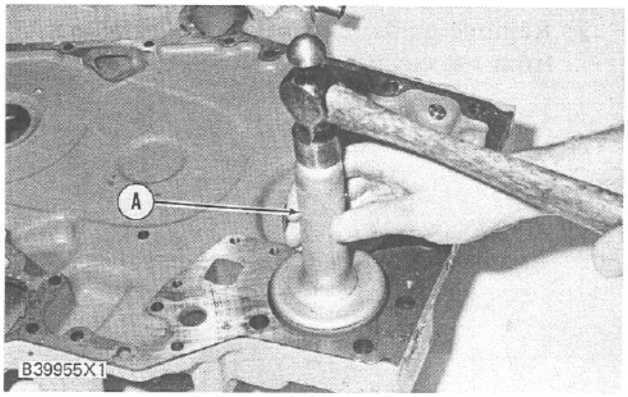
1. Thoroughly clean all of the parts. Put oil on all of the pump parts.



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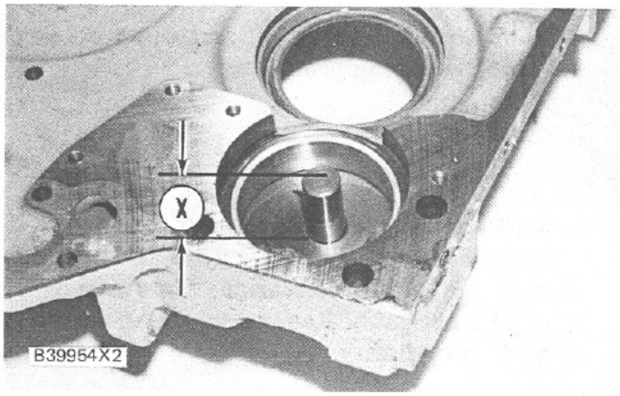
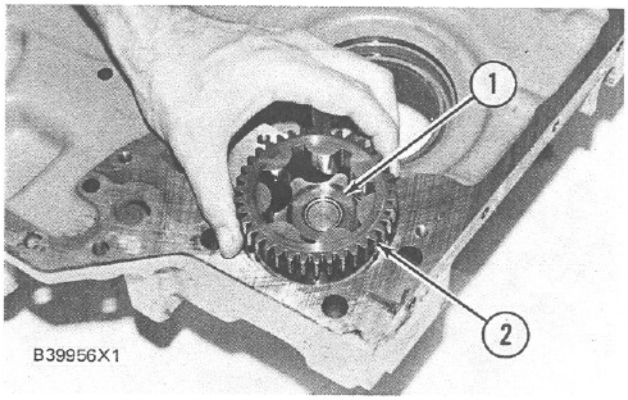
2. If the bearing was removed from the timing gear cover, install a new bearing with tool (A). Make sure the bearing is installed with the joint in the position shown in the illustration.



B39954X2

3. If the shaft was removed from the timing gear cover, install the new shaft so dimension "X" from the top of the shaft to the counterbore in the cover is 36.14 ± 0.25 mm (1.423 ± .010 in.).

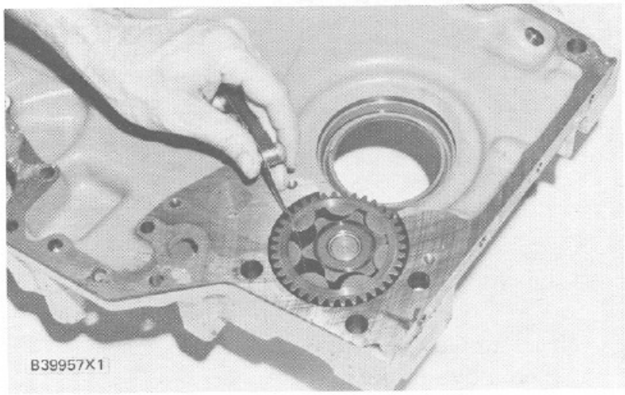


B39956X1

4. Install inner rotor (1) and outer rotor (2) in the timing gear cover.

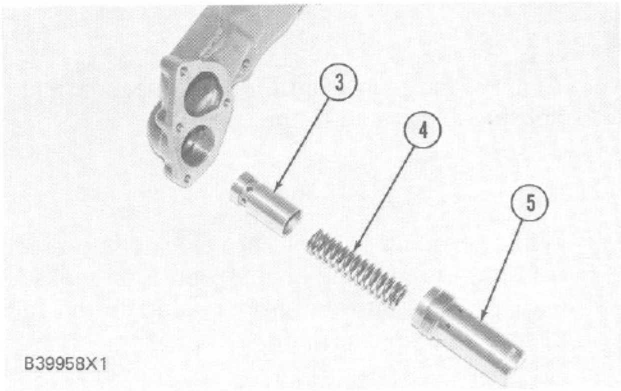
OIL PUMP AND RELIEF VALVE

5. Measure the clearance between the rotors with a feeler gauge. The clearance must be 0.05 to 0.20 mm (.002 to .008 in.). The maximum permissible clearance is 0.28 mm (.011 in.).

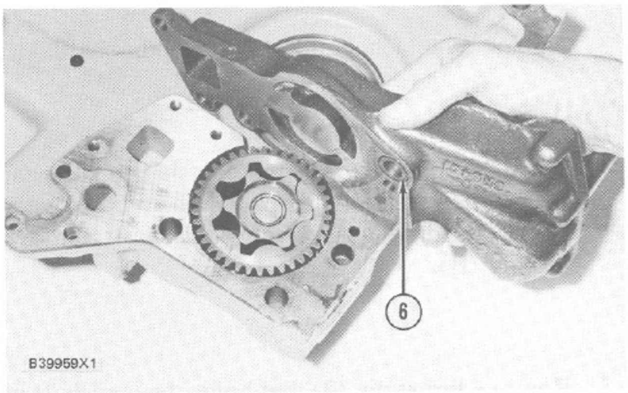


NOTE: Make a replacement of BOTH rotors if the clearance is not correct. The rotors can not be ordered separately.

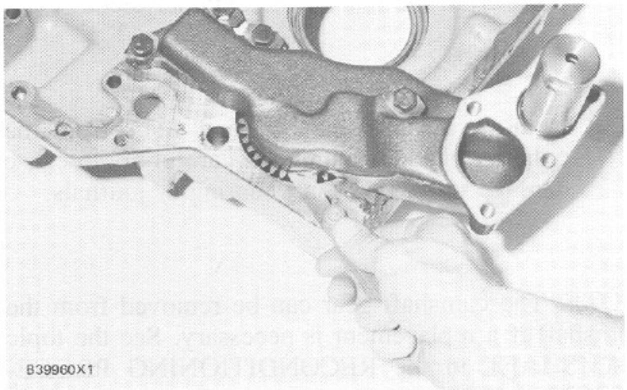
6. Put plunger (3), spring (4) and guide (5) in the cover. Use a 1-1/8 in. crowfoot wrench and torque wrench to tighten guide (5) to a torque of 41 ± 7 N•m (30 ± 5 lb.ft.). A slide rule type torque computer, Form No. SEHS7150, is available to find the torque wrench dial reading for different extensions.



7. Install O-ring seal (6) on the cover and put the cover in position on the timing gear cover. Install the locks and bolts that hold the cover in place.



8. Check the oil pump and clearance with a feeler gauge. The end clearance must be 0.069 to 0.135 mm (.0027 to .0053 in.).



NOTE: If the clearance is not correct, make a replacement of BOTH rotors or the cover.

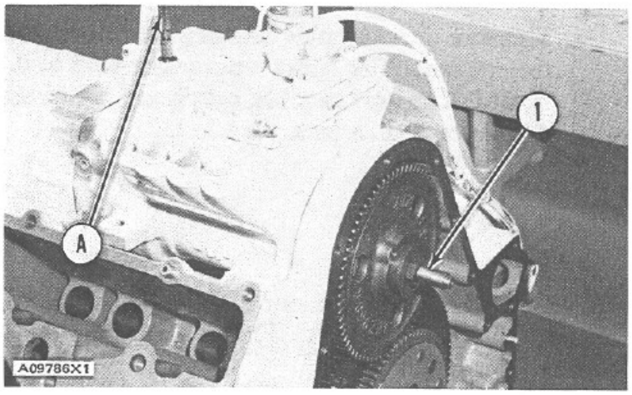
end by:
a) install timing gear cover and oil pump

CAMSHAFT AND GEARS

REMOVE CAMSHAFT AND GEARS 1210 & 1212-11

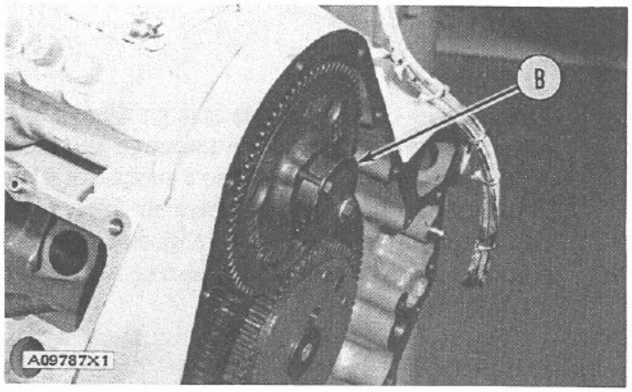
	Tools Needed	A	B
3P1544	Timing Pin	1	
5P2371	Puller Plate		1
	Bolt (¼"-20 NC x 1" long)		2
	Flat Washer ¼"		2

start by:
a) remove timing gear cover and oil pump
b) remove valve lifters
c) remove turbocharger



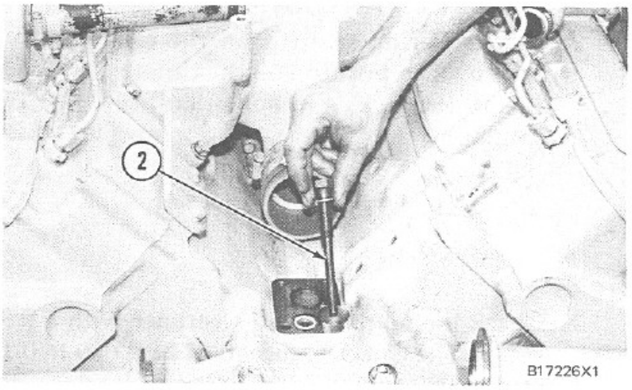
1. Remove the plug from the fuel injection pump housing and install timing pin (A).

2. While the crankshaft is turned clockwise (as seen from the front of the engine), push on tool (A) until it slides into the groove (slot) in the fuel injection pump camshaft.



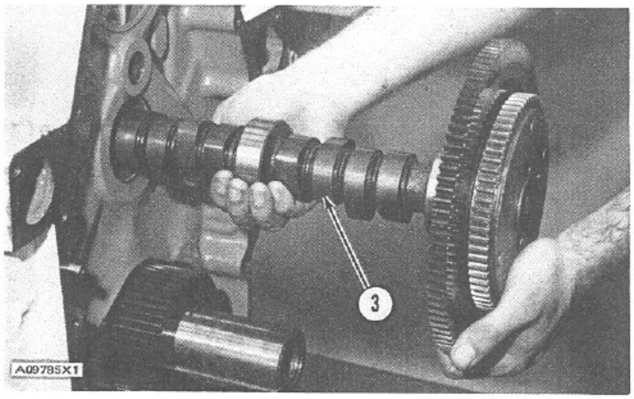
3. Remove the tachometer drive adapter shaft (1).

4. Install tooling (B) into the camshaft drive gear for the fuel injection pump. Turn both bolts evenly until the drive gear is free of the shaft. Remove tooling (B).



5. Remove thrust pin (2) that holds the camshaft in place from the rear of the cylinder block.

6. Remove the camshaft (3) and gears from the cylinder block as a unit. Be careful not to cause damage to the camshaft bearing or journals.



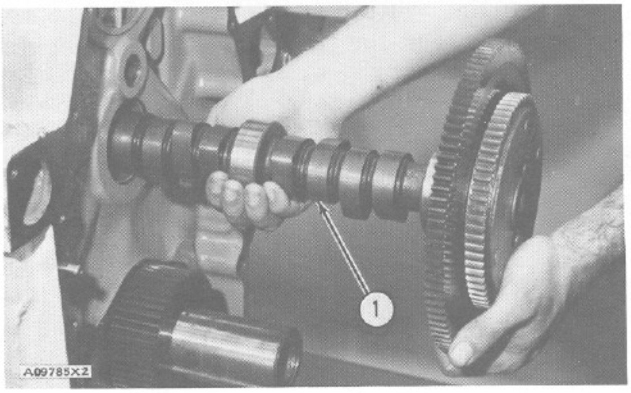
NOTE: The camshaft gear can be removed from the camshaft if a replacement is necessary. See the topic CAMSHAFT in the RECONDITIONING PROCEDURES.

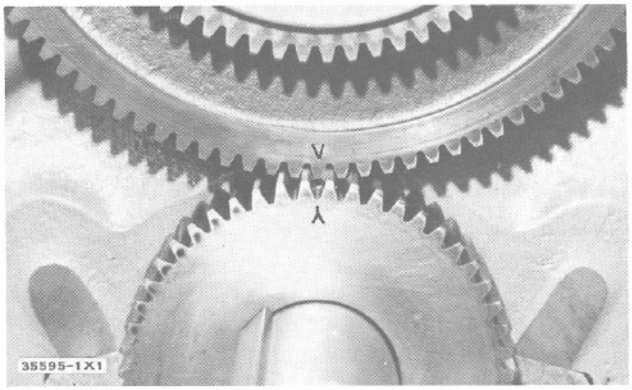
CAMSHAFT AND GEARS

INSTALL CAMSHAFT AND GEARS 1210 & 1212—12

	Tools Needed	A
3P1544	Timing Pin	1

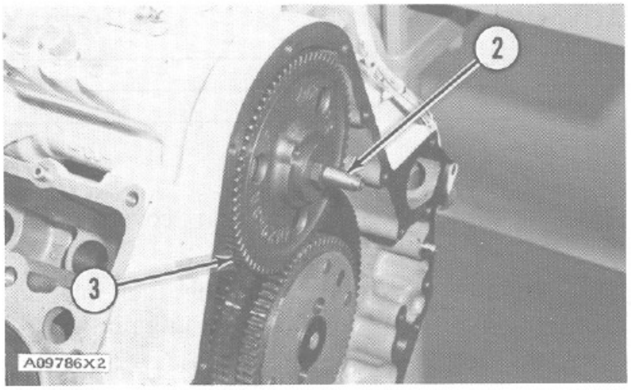
1. Install the camshaft gear on the camshaft if it was removed. Heat the gear to a maximum temperature of 315°C (600°F). Put the gear in position on the camshaft. Put clean engine oil on the camshaft lobes and journals. Install camshaft (1) and the gears as a unit. Make sure the timing marks on the crankshaft gear and camshaft gear are in alignment.





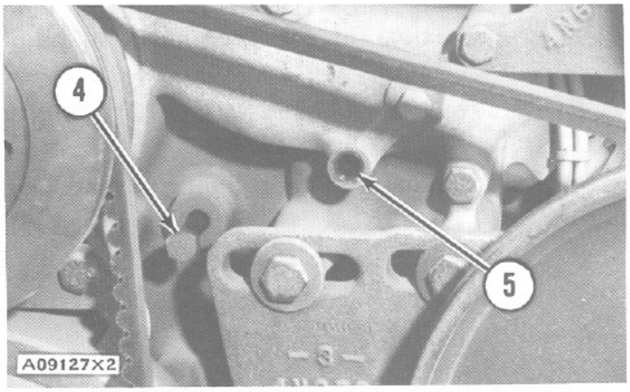
2. Install the thrust pin. Tighten the pin to a torque of 45 ± 7 N•m (35 ± 5 lb.ft.).

3. Put gear (3) in position and install tachometer drive adapter shaft (2). Tighten the shaft to the correct torque.



NOTE: For the correct torque, see the topic DRIVE GEAR FOR THE INJECTION PUMP in the SPECIFICATIONS.

4. After valve lifters and timing gear cover have been installed, check the timing as follows:
   a) Remove timing pin (A).
   b) Turn the crankshaft clockwise as seen from the front of the engine approximately 1/2 turn. Install timing pin (A) again.
   c) While turning the crankshaft clockwise, push on timing pin (A) until it slides into the groove (slot) in the fuel injection pump camshaft.
   d) Remove the plug from the timing hole in the front cover and install a 5/16"–18 NC bolt (4) 2 1/2 in. long. The cover bolt from hole (5) can be used. Turn the crankshaft clockwise until bolt (4) can be installed into the timing gear and is in the center of the timing hole. The camshaft for the fuel injection pump is now in correct time with the engine.
   e) Remove the bolt and install the plug. Remove timing pin (A) and install the plug.



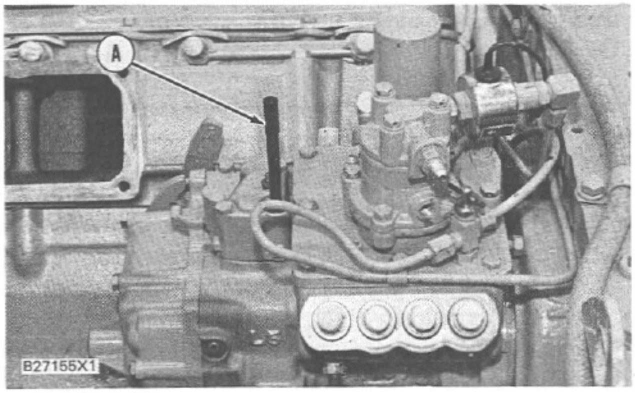
CAMSHAFT AND GEARS, AUTOMATIC TIMING ADVANCE

NOTE: If the bolt can not be installed in the hole of camshaft gear, the timing must be corrected as follows:

a) With timing pin (A) installed, remove the tachometer drive adapter housing and shaft.

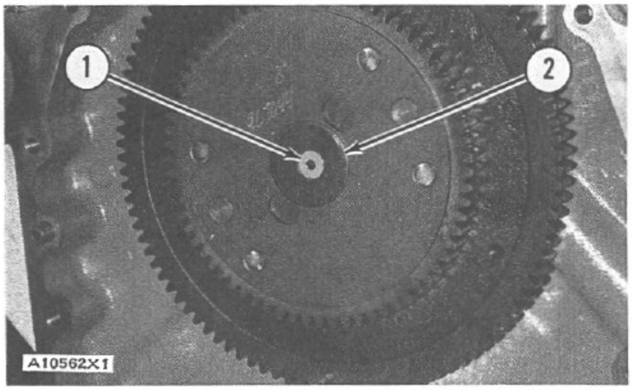
b) Loosen the gear from the fuel injection pump camshaft. Turn the crankshaft clockwise approximately two full turns until bolt (4) can be installed. Install the bolt.

c) Install tachometer drive adapter shaft and tighten it to the correct torque. Install adapter housing. Remove the bolt and timing pin and install the plugs.



NOTE: For the correct torque, see the topic DRIVE GEAR FOR THE INJECTION PUMP in the SPECIFICATIONS.

end by:
a) install valve lifters
b) install timing gear cover and oil pump
c) install turbocharger

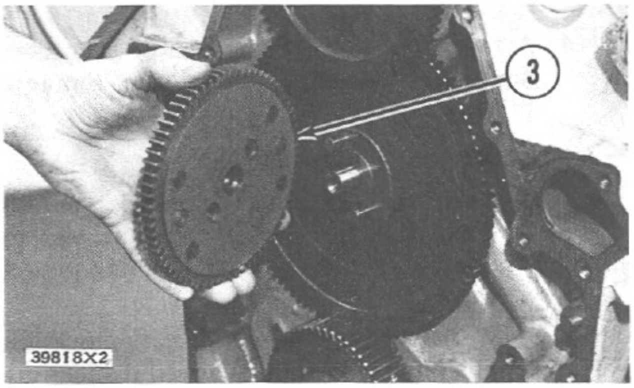


REMOVE AUTOMATIC TIMING ADVANCE 1272—11

	Tools Needed	A
3P1544	Timing Pin	1

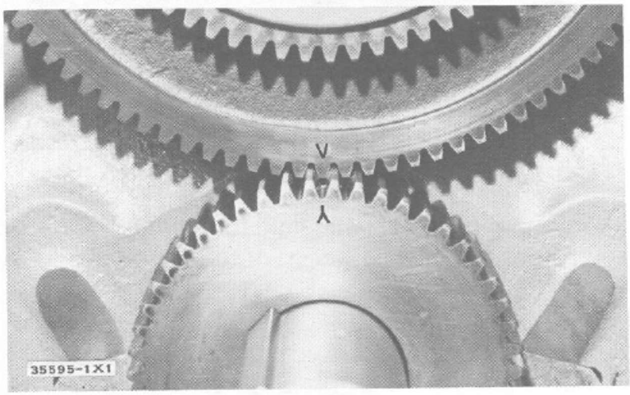
start by:
a) remove timing gear cover and oil pump

1. Remove the plug from the fuel injection pump housing and install timing pin (A).
2. While turning the crankshaft clockwise (as seen from the front of the engine), push on the timing pin (A) until it slides into the groove (slot) in the fuel injection pump camshaft.
3. Remove screw (1) and washer (2) from the end of the engine camshaft.
4. Remove the automatic timing advance (3).



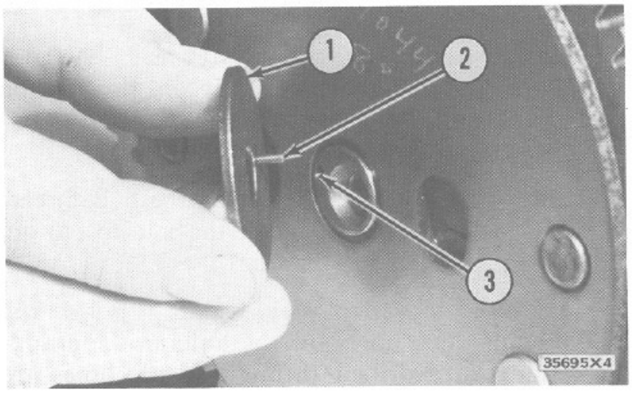
AUTOMATIC TIMING ADVANCE

INSTALL AUTOMATIC TIMING ADVANCE 1272—12



1. If the timing mark on the crankshaft and the timing mark on the camshaft gear are not in alignment, turn the crankshaft clockwise (as seen from the front of the engine) until the marks are in alignment.

2. Put the dowels in the gear in alignment with the holes in the weights and install the automatic timing advance .

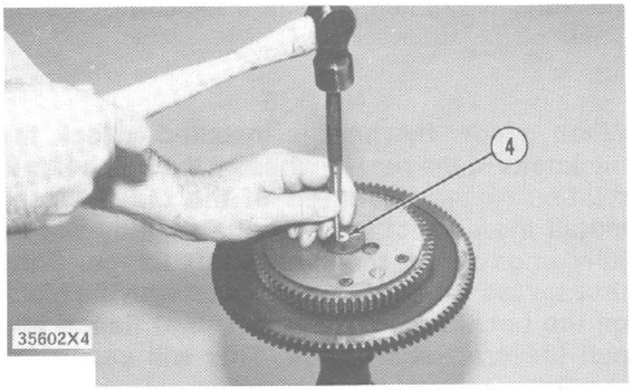


3. Put pin (2) in washer in alignment with hole (3) in the camshaft and install washer (1).

4. Install screw (4) and tighten it to a torque of 7.9 ± 0.6 N•m (70 ± 5 lb.in.). Put marks (stake) on the screw in two places with a hammer and punch.

NOTICE

Put marks (stake) on screw (4) carefully. Too much force pushes the shaft extension into the camshaft and takes away all end clearance.



CAMSHAFT REMOVED FOR PHOTO ILLUSTRATION

5. After marks (stake) are put on screw (4), the end clearance for the gear and weight assembly must be 0.08 to 0.94 mm (.003 to .037 in.). This end clearance will prevent binding against the washer, camshaft end, or camshaft gear.

end by:

a) install timing gear cover and oil pump

FLYWHEEL, FLYWHEEL HOUSING

REMOVE FLYWHEEL 1156-11

	Tools Needed	A
FT121	Lifting Bracket	1
S509	Bolt (3/8"-16 NC x 1 in. long)	1

1. Fasten tool (A) and a hoist to flywheel (2).
2. Remove bolts (1) that hold the flywheel. Remove the flywheel. The weight of the flywheel is 31 kg (60 lb.).

INSTALL FLYWHEEL 1156-12

	Tools Needed	A
FT121	Lifting Bracket	1
S509	Bolt (3/8"-16 NC x 1 in. long)	1

1. Install tooling (A) on the flywheel. Fasten a hoist and put flywheel (1) in position on the crankshaft. Make sure the marks on the flywheel and crankshaft are in alignment.
2. Put 8H5137 Gasket Sealer on the bolt threads and install the bolts. Tighten the bolts to a torque of 75 ± 7 N•m (55 ± 5 lb.ft.).

NOTE: Make sure the correct sealant is put on the bolt threads. The holes for the bolts in the crankshaft flange are drilled through so the holes are open to the oil in the engine. Leakage along the bolt threads can be the result if the correct sealant is not used.

NOTICE

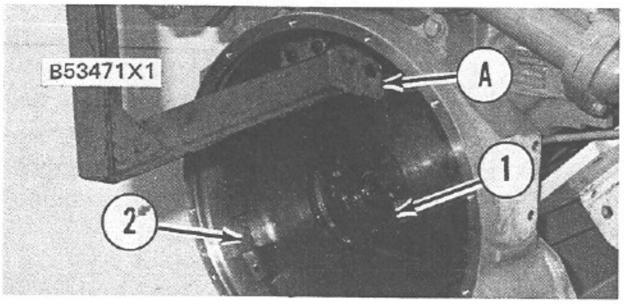
When a new flywheel is installed, check the thickness of the new flywheel at the bolt holes in relation to the thickness of the old flywheel. Install the correct length bolts so they will be fully engaged in the crankshaft flange. Bolts that are too long will make contact with the block on the back side of the crankshaft flange and pull the crankshaft back. This will cause the crankshaft thrust bearing to fail.

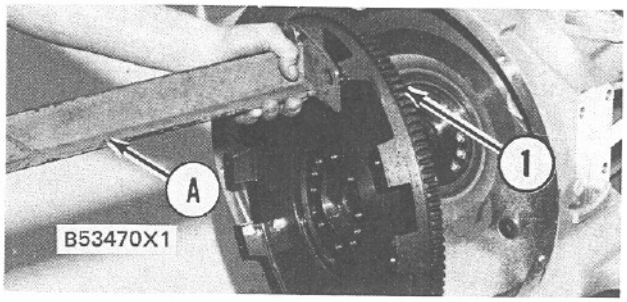
REMOVE FLYWHEEL HOUSING 1157-11

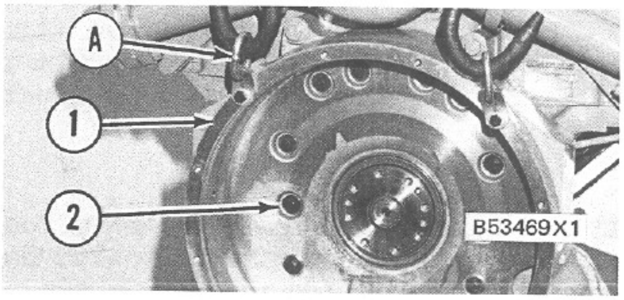
	Tools Needed	A
5P9736	Link Bracket	2

start by:
a) remove starter
b) remove flywheel

1. Loosen the bolts that hold the oil pan to the cylinder block. Remove the bolts that hold the oil pan to the flywheel housing. Fasten tooling (A) and a hoist to the rear of the engine. Lift the rear of the engine and install shims on each side of the cylinder block.







2. Remove the bolts (2) that hold the flywheel housing in place. Remove flywheel housing (1).

INSTALL FLYWHEEL HOUSING 1157-12

	Tools Needed	A
5P9736	Link Bracket	2

1. Clean the contact surfaces of the flywheel housing and cylinder block. Install a new gasket.
2. Put oil on the lip of the rear seal. Put flywheel housing in position and install the bolts.
3. Cut the gasket so it is even with the bottom of the block and flywheel housing. Remove the shims from each side of the block and tighten the bolts for the oil pan. Install remainder of bolts in oil pan.

end by:
a) install flywheel
b) install starter

CRANKSHAFT REAR SEAL AND WEAR SLEEVE

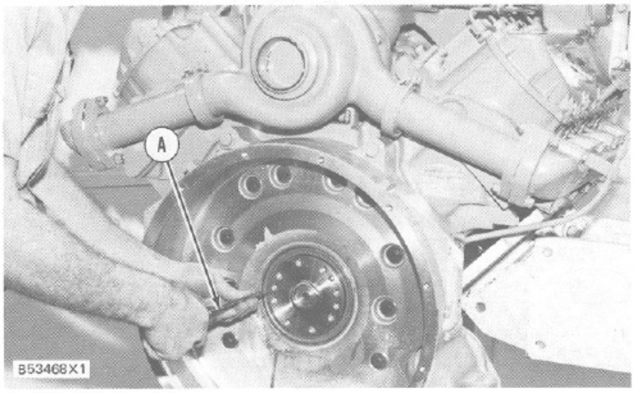
REMOVE CRANKSHAFT REAR SEAL AND WEAR SLEEVE 1161—11

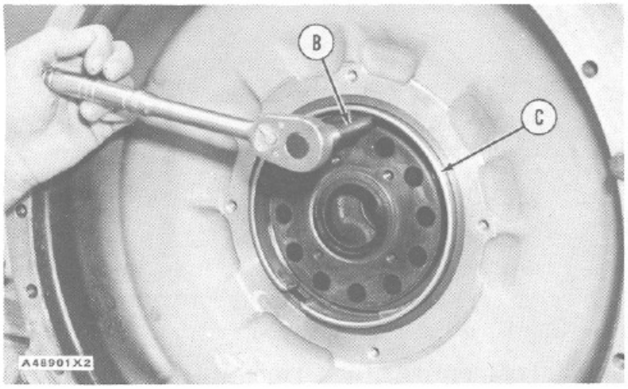
Tools Needed		A	B	C
1P3075	Puller Assembly	1		
5P7312	Distorter		1	
5P7338	Ring			1

start by:
  a) remove flywheel

NOTE: When a replacement of the rear seal is made, a replacement of the wear sleeve is to be made also.

1. Remove the crankshaft rear seal from the flywheel housing with tooling (A).
2. Install tool (C) in the rear seal bore.
3. Install tool (B) between tool (C) and the wear sleeve. Turn tool (B) until the edge of the tool makes a flat place (crease) in the wear sleeve. Do this in two or more places until the wear sleeve is loose.
4. Remove tool (C) and the wear sleeve by hand.



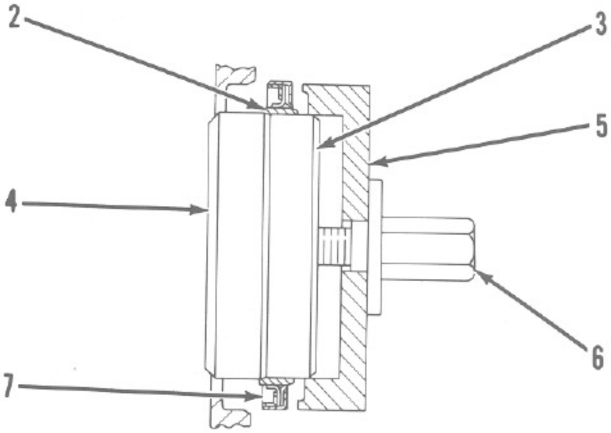


INSTALL CRANKSHAFT REAR SEAL AND WEAR SLEEVE 1161—12

Tools Needed		A
5P7293	Installer	1
5P290	Locator	1
1P5515	Bolt	2
9S8858	Nut	1

NOTICE

The crankshaft seal and wear sleeve come as a set and must not be separated from each other at any time. Carefully read Special Instruction, Form No. SMHS8508, that is included with each seal and wear sleeve before any handling of the seal group is made.



B84143P4

1. Install the crankshaft rear seal and wear sleeve with tooling (A) as follows:
   a) Clean and make a preparation of the crankshaft outside diameter with 6V1541 Quick Cure Primer. Make an application of 9S3265 Retaining Compound to crankshaft outside diameter.
   b) Install locator (3) and the bolts on the rear of the crankshaft (4).
   c) Put the wear sleeve (2) and seal (7) as a unit on locator (3) with the outside diameter bevel of the wear sleeve toward the outside.
   d) Put installer (5) in position on the locator (3).
   e) Put clean engine oil on the face of nut (6) and install it on the locator. Tighten the nut until installer (5) is at bottom.
   f) Remove tooling (A) and check the wear sleeve and seal for the correct position after installation.

end by:
  a) install flywheel

CRANKSHAFT AND GEAR

REMOVE CRANKSHAFT AND GEAR 1202 & 1204-11

	Tools Needed	A	B
	OTC Model 1730-A Engine Stand	1	
8B7551	Bearing Puller Attachment		1
1P820	Puller Group		1
8B7549	Leg		2
8B7561	Step Plate		1
3H465	Plate		4
1B4207	Nut		2
5P3100	Pump Group		1

start by:

a) remove flywheel housing
b) remove valve lifters
c) remove pistons
d) remove timing gear cover and oil pump

1. Fasten a hoist and put the engine in position on tool (A).
2. Turn the crankshaft until the timing mark on the crankshaft gear is in alignment with the timing mark on the camshaft gear.

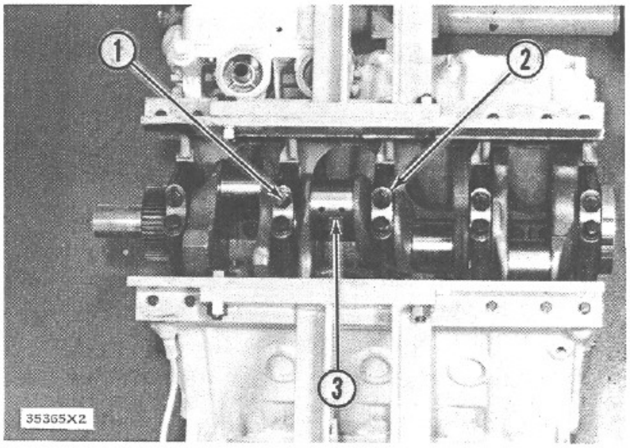
NOTE: For more detail about removal of main bearings see REMOVE AND INSTALL CRANKSHAFT MAIN BEARINGS.

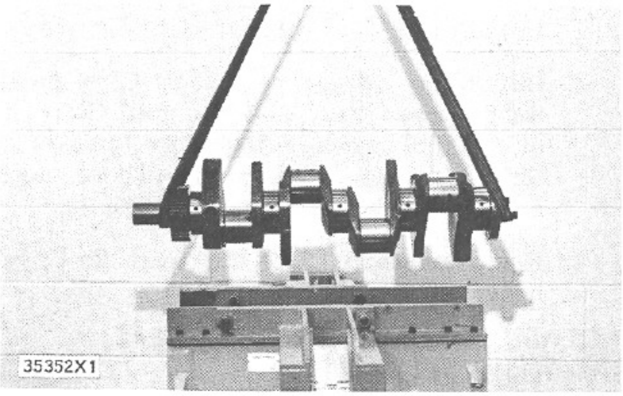
3. Remove bolts (1) and main bearing caps (2). Remove the lower halves of the main bearings from the caps.
4. Install two of the bolts that hold the flywheel in place in the end of crankshaft.
5. Fasten a hoist and remove crankshaft (3) from the engine. The weight of the crankshaft is 54 kg (120 lb.).

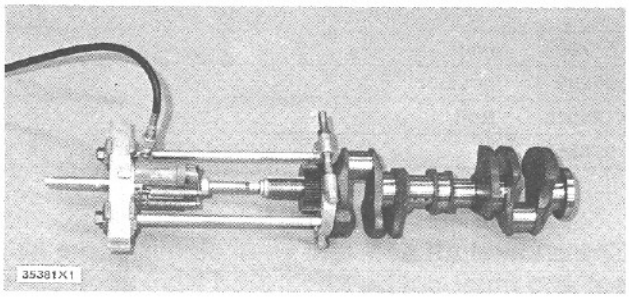
NOTICE

Be careful not to cause damage to the crankshaft journals when the crankshaft is removed.

6. Remove the upper halves of the main bearings from the cylinder block.
7. Install tooling (B) and remove the gear from the crankshaft.







CRANKSHAFT AND GEAR

INSTALL CRANKSHAFT AND GEAR 1202 & 1204-12

	Tools Needed	A	B
8S2328	Dial Test Indicator Group	1	
	Plastigage		*

1. Install the key for the crankshaft gear so it is even with the end of the crankshaft.

2. Heat the crankshaft gear to a maximum temperature of 260°C (500°F). Install the gear on the crankshaft with the timing mark on the gear toward the pulley end of the crankshaft.

3. Install the thrust bearing for the No. 4 main.

NOTE: Install the bearings dry when the clearance checks are made. Put clean engine oil on the bearings for final assembly.

4. Install the upper main bearings (the bearings with oil hole) into the engine block.

5. Install two of the bolts that hold the flywheel in place in the end of the crankshaft. Fasten a hoist and put the crankshaft in position in the block. Make sure the timing mark on the crankshaft gear is in alignment with the timing mark on the camshaft gear.

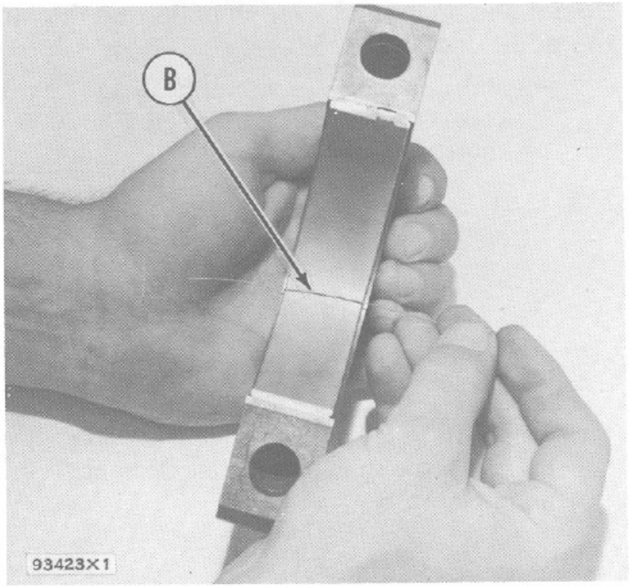
NOTE: For more detail about installation of main bearings see REMOVE AND INSTALL CRANKSHAFT MAIN BEARINGS.

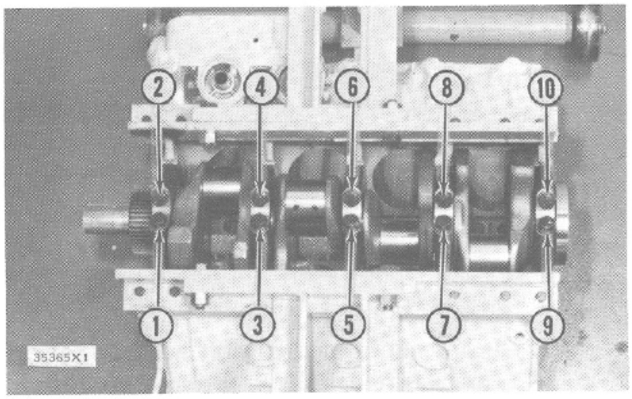
NOTICE

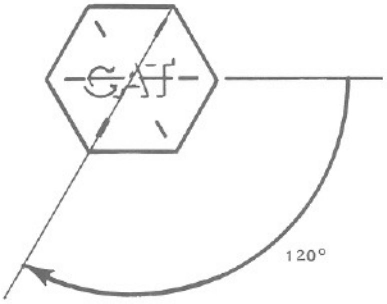
When the bearing caps are installed, make sure the number on the side of the cap is next to and respective with the number on the engine block.

NOTE: When the bearing clearance is checked and the engine is in a vertical position, the crankshaft will have to be lifted up with a force equal to the weight of the crankshaft and held against the upper halves of the main bearings to get a correct measurement with Plastigage. The Plastigage will not hold the weight of the crankshaft and give a correct indication. If the engine is in a horizontal position, such as on an engine stand, it is not necessary to hold the crankshaft up. Do not turn crankshaft when Plastigage is in position to check clearance.

6. Check the bearing clearance with Plastigage. Put the lower main bearings into the caps. Put the caps in position and install the bolts. Tighten the bolts in number sequence as follows:
   a) Tighten bolts 1 through 10 to a torque of 40 ± 4 N•m (30 ± 3 lb.ft.).







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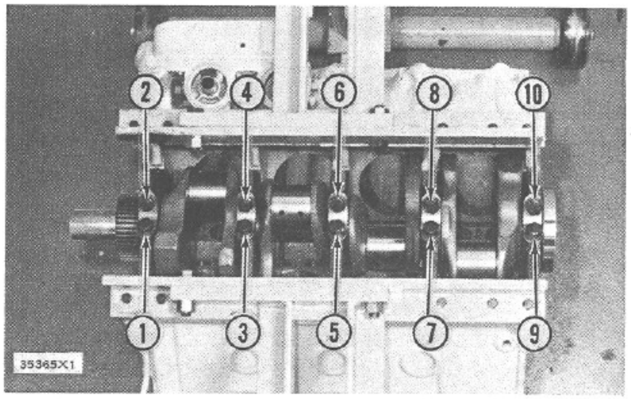
CRANKSHAFT AND GEAR

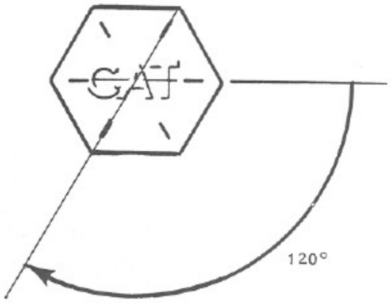
NOTICE

Do not use an impact wrench to tighten the nuts the additional 120 ± 5°.

b) Put a mark on each bolt head and bearing cap. Tighten bolts 1 through 10 120 ± 5° more.



7. Remove the bearing caps and measure the thickness of the Plastigage. The main bearing clearance must be 0.076 to 0.168 mm (.0030 to .0066 in.). The maximum permissible clearance is 0.18 mm (.007 in.).



30912X1

8. Put 2P2506 Thread Lubricant on the bolt threads and washer faces. Put clean engine oil on the main bearings. Put the bearing caps in position and install the bolts. Tighten the bolts in number sequence as follows:
   a) Tighten bolts 1 through 10 to a torque of 40 ± 4 N•m (30 ± 3 lb.ft.).
   b) Put a mark on each bolt head and bearing cap. Tighten bolts 1 through 10 120 ± 5° more.

9. Install indicator group (A) and check the end play of the crankshaft. The end play is controlled by the thrust bearing on No. 4 main bearing. The end play with new bearing must be 0.08 to 0.25 mm (.003 to .010 in.). The maximum permissible end play with used bearing is 0.36 mm (.014 in.).

end by:
a) install timing gear cover and oil pump
b) install pistons
c) install valve lifters
d) install flywheel housing

CAMSHAFT BEARINGS

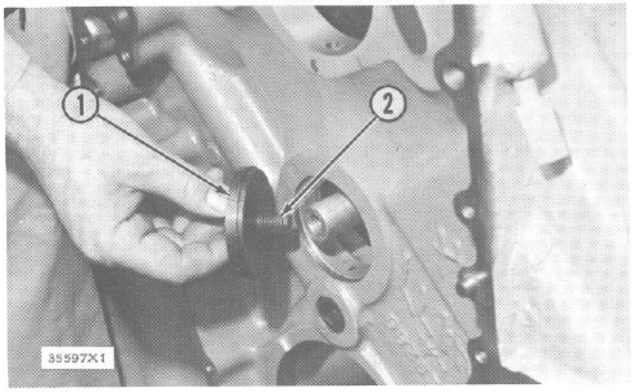
REMOVE CAMSHAFT BEARINGS 1211-11

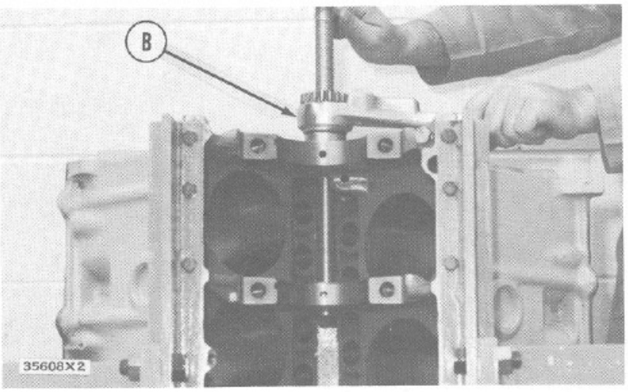
	Tools Needed	A	B
1P5545	Adapter Group	1	
8S2241	Camshaft Bearing Installation and Removal Group		1
8H684	Ratchet Box Wrench		1

start by:
a) remove crankshaft and gear
b) remove camshaft and gears

NOTE: The crankshaft does not have to be removed for removal and installation of the camshaft bearings, but must be removed to correctly clean the oil passages in the cylinder block.

1. Install tooling (B) through the flywheel housing end of the cylinder block.
2. Install washer (1) and bolt (2) from tool group (A) in the end of the shaft of tooling (B). Remove the bearings from the cylinder bolck. Start with the front bearing.
3. Thoroughly clean the oil passages and surfaces where the camshaft and bearings fit.

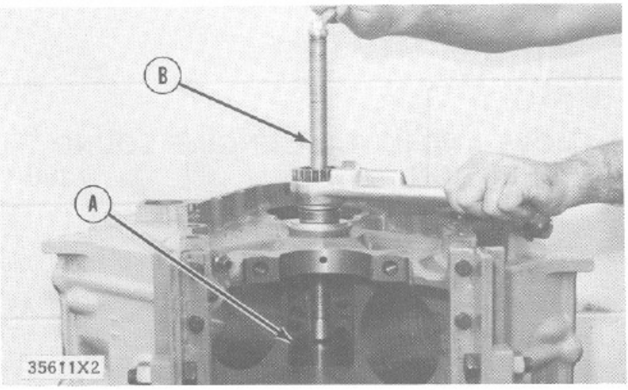




INSTALL CAMSHAFT BEARINGS 1211—12

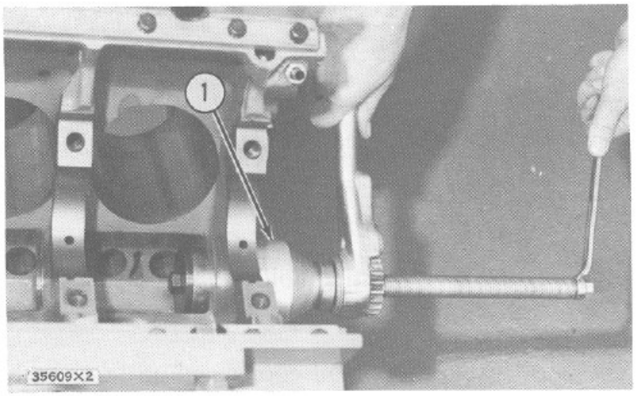
	Tools Needed	A	B
1P5545	Adapter Group	1	
8S2241	Camshaft Bearing Installation and Removal Group		1
8H684	Ratchet Box Wrench		1

1. Start with the rear camshaft bearing and install the bearings in the cylinder block with tooling (A) and (B). Make sure the oil holes in the bearing are in alignment with the oil holes in the cylinder block.



2. To install the front camshaft bearing, put tube (1) from tool group (B) in position shown with the tube over the boss on the front of the cylinder block and pull the bearing into place. Make sure the oil holes in the bearings are in alignment with the oil holes in the cylinder block.

end by:
a) install camshaft and gears
b) install crankshaft and gear



STARTER, ENGINE SOUND SUPPRESSION

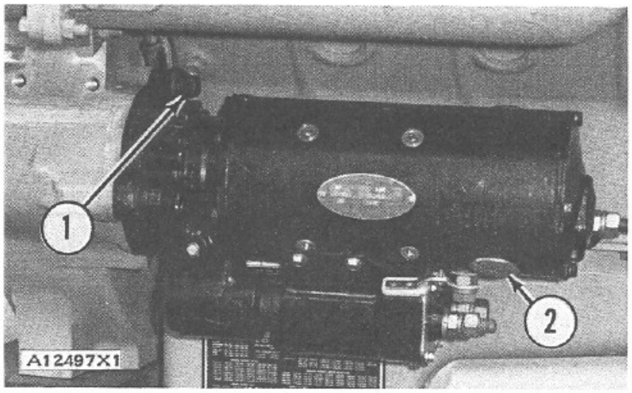
REMOVE STARTER

1453-11

1. Disconnect the battery cables.

2. Disconnect and put identification on the wiring.

3. Remove bolts (1) and starter (2).



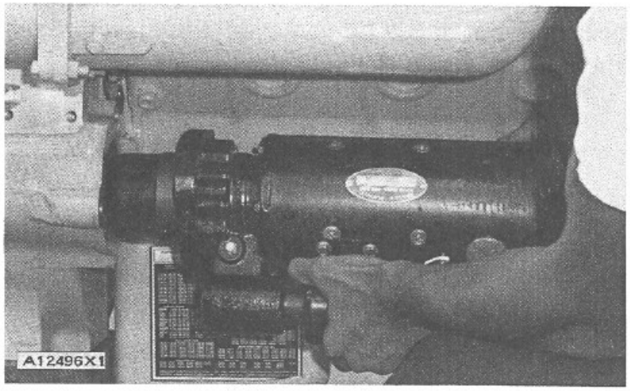
INSTALL STARTER

1453-12

1. Put the starter in position on the engine.

2. Install the bolts.

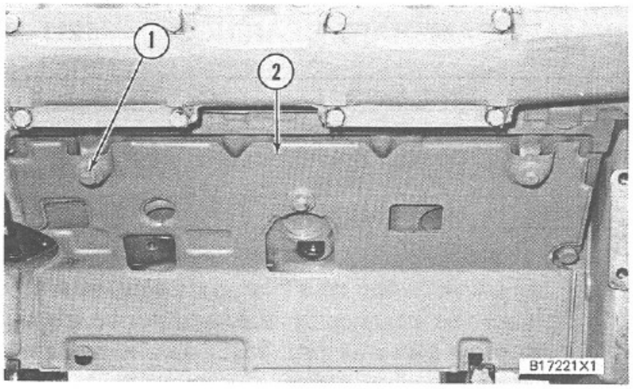
3. Connect the wiring and battery cables.



REMOVE AND INSTALL ENGINE SOUND SUPPRESSION 7260-10

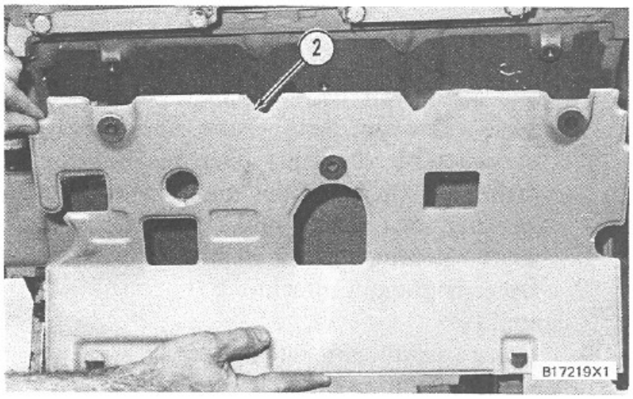
start by:
a) remove engine oil cooler and oil filter base

1. Remove three bolts (1) and remove sound suppression (2).



2. Put sound suppression (2) in position.

3. Install the bolts that hold the sound suppression in place.
end by:
a) install engine oil cooler and oil filter base



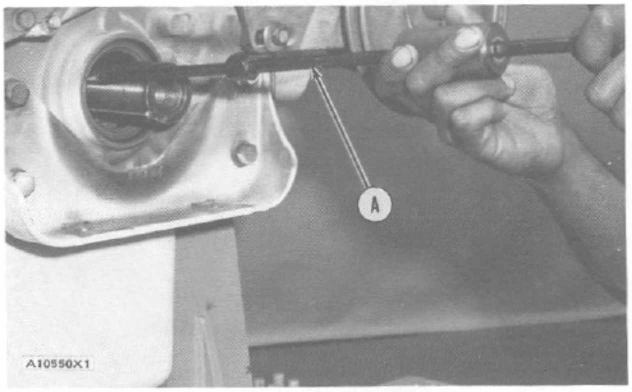
CRANKSHAFT FRONT SEAL

REMOVE CRANKSHAFT FRONT SEAL 1160—11

Tools Needed		A
1P3075	Puller Group	1

start by:
a) remove crankshaft pulley

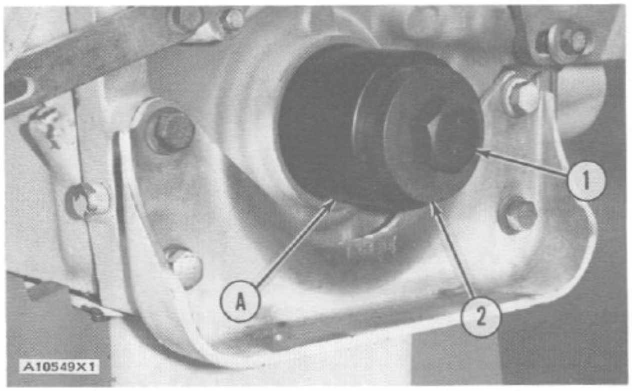
1. Remove the front seal with tool group (A).



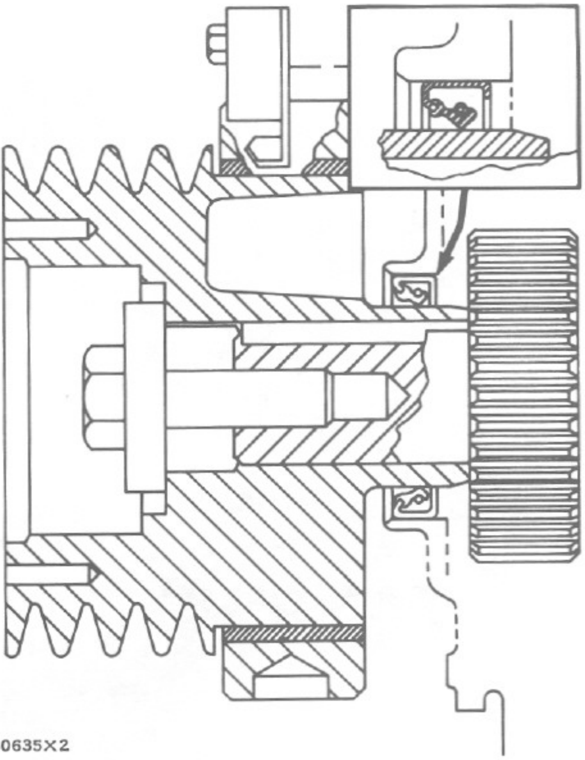
INSTALL CRANKSHAFT FRONT SEAL 1160—12

Tools Needed		A
5P4194	Installer Assembly	1
2H3745	Bolt (1"-14 NF x 2 3/4 in. long)	1

1. Put 7F2770 Cement on the outer metal surface of the front seal. Put the seal in position on the short end of the installer assembly (A). The lip of the seal must be toward the inside of the engine.



NOTE: If a new wear surface for the front seal is needed, put the spacer from tooling (A) between the seal and flange of the installer assembly.


30635X2

2. Put the seal and installer assembly in position on the end of the crankshaft. Install washer (2) that is used to hold the crankshaft pulley and the 2H3745 Bolt (1). Tighten the bolt until the installer assembly makes contact with the crankshaft gear. Remove tooling (A) and washer (2).

end by:
a) install crankshaft pulley

AIR COMPRESSORS (Section 7)

Tu-Flo 501 Air Compressor

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IMPORTANT! PLEASE READ

When working on or around air brake systems and components, the following precautions should be observed:

1. Always block vehicle wheels. Stop engine when working under a vehicle. Depleting vehicle air system pressure may cause vehicle to roll. Keep hands away from chamber push rods and slack adjusters; they may apply as system pressure drops.
2. Never connect or disconnect a hose or line containing air pressure. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been depleted.
3. Never exceed recommended air pressure and always wear safety glasses when working with air pressure. Never look into air jets or direct them at anyone.
4. Never attempt to disassemble a component until you have read and understand recommended procedures. Some components contain powerful springs and injury can result if not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

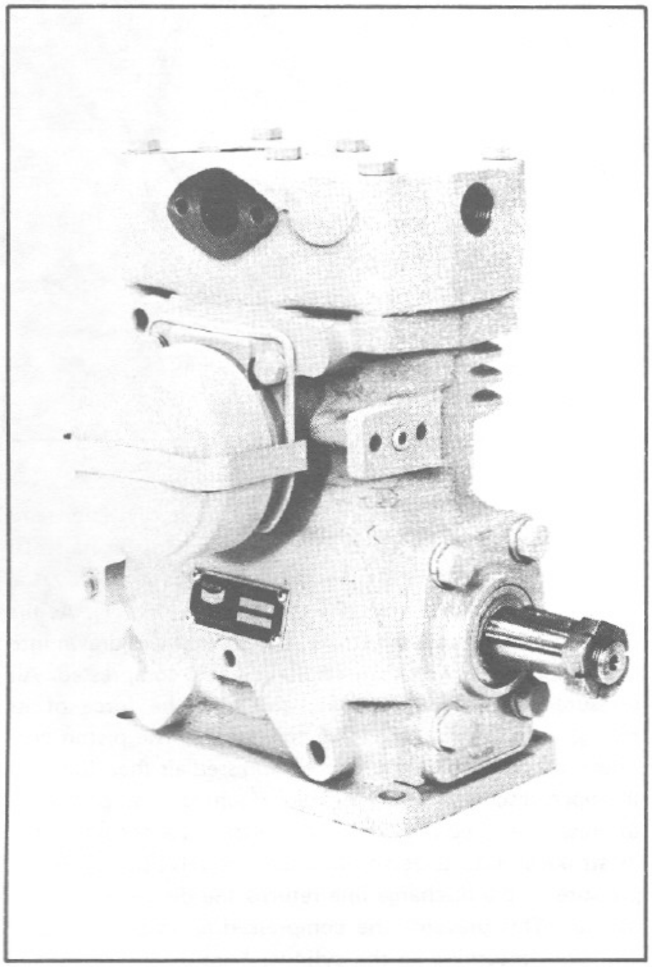
Bendix

Heavy Vehicle Systems Group

Service Data

SD-01-3
Formerly SD-64

TU-FLO 501 AIR COMPRESSOR



DESCRIPTION AND OPERATION

General

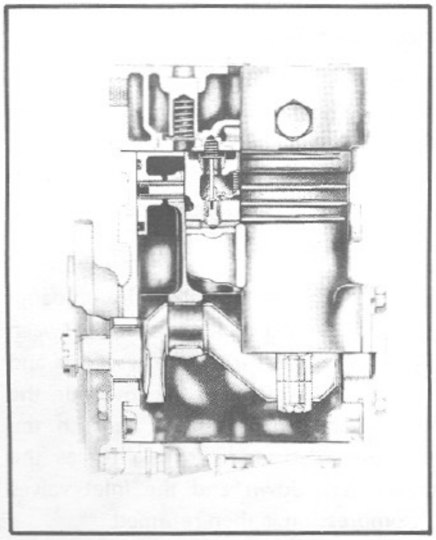
The function of the air compressor is to provide and maintain air under pressure to operate devices in the air brake and/or auxiliary air systems.

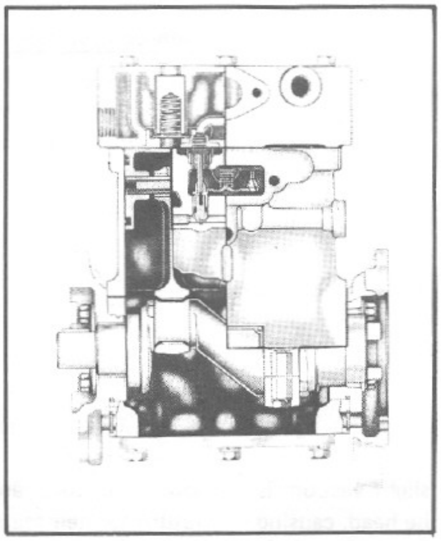
Description

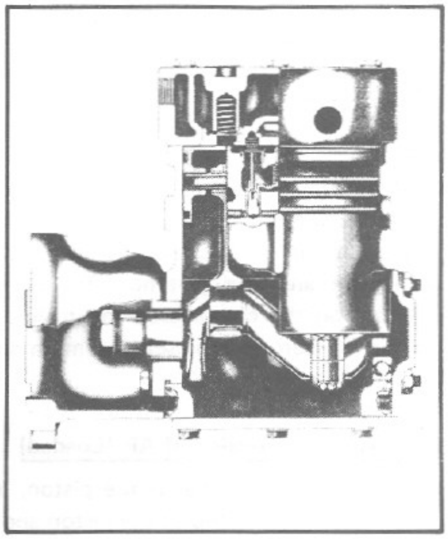
The Tu-Flo 501 is a two cylinder, single stage, reciprocating compressor with a rated displacement of 12 cubic feet of air per minute at 1250 R.P.M.

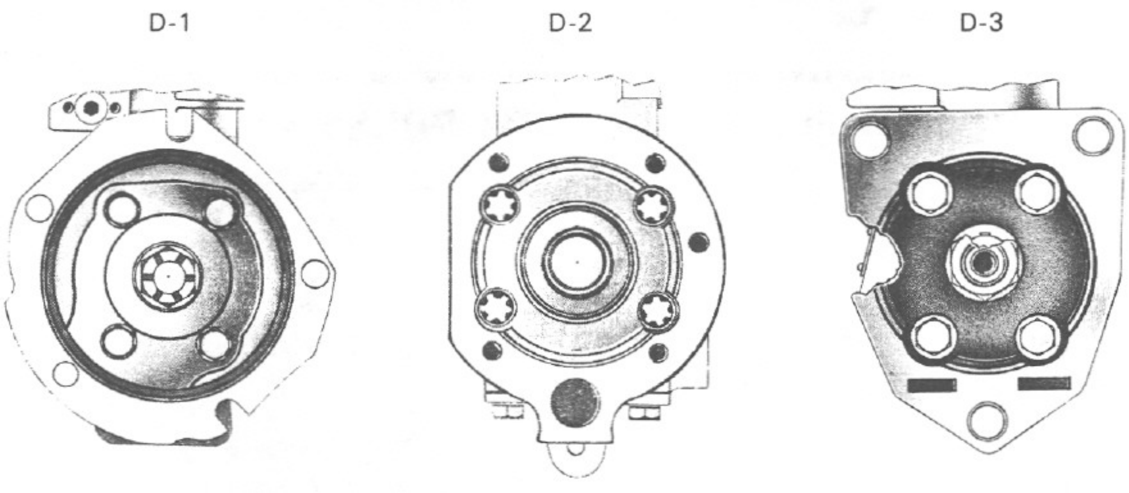
The Tu-Flo 501 is constructed from two major assemblies, the head and the crankcase. The head houses the discharge valving and is installed on the upper portion of the crankcase. The crankcase is a one piece casting combining the cylinder block and the crankcase. The upper portion of the casting houses the cylinder bores and inlet valving; and the lower portion, the crankshaft and main bearings. Various mounting and drive configurations, required by the numerous vehicle engine designs, are obtained by bolting different mounting flanges, end covers, and base adapters to the crankcase. Two horizontal governor mounting pads are located on either side of the upper portion of the crankcase to provide convenient governor mounting.

Two methods are employed for cooling the Tu-Flo 501 during operation. The cylinder head is connected to the engine's cooling system, while the cylinder bore portion of the crankcase has external fins for efficient air cooling.





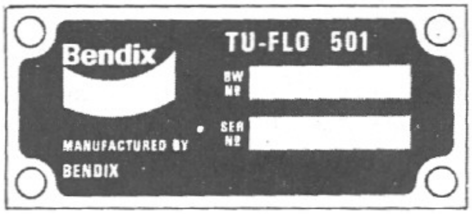




VARIOUS COMPRESSOR MOUNTINGS

All Tu-Flo 501 compressors utilize the engine's pressurized oil system to lubricate the internal moving parts.

A nameplate is attached to the crankcase to identify the compressor. The nameplate displays a Bendix piece number or in some cases an engine or vehicle manufacturer's piece number, along with a serial number.



COMPRESSOR NAMEPLATE

OPERATION

General

The compressor is driven by the vehicle engine and is operating continuously while the engine is running. Actual compression of air is controlled by the compressor unloading mechanism and the governor. The governor is generally mounted on the compressor and maintains the brake system air pressure to a preset maximum and minimum pressure level.

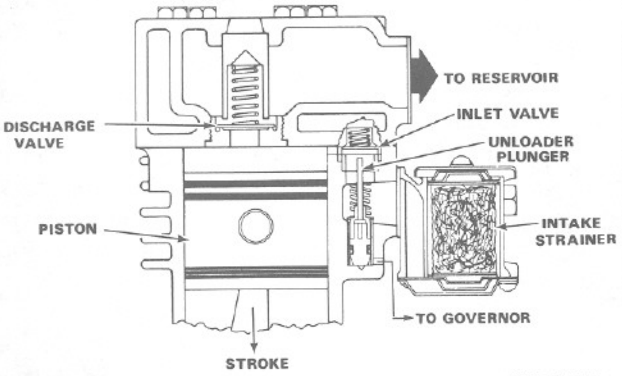
Intake and Compression of Air (Loaded)

During the down stroke of the piston, a slight vacuum is created between the top of the piston and the head, causing the flat circular inlet valve to move up and off its seat. (Note the flat square discharge valve remains on its seat.) Atmospheric air is drawn through the air strainer by the open inlet valve and into the cylinder (see Fig. 1). As the piston begins its upward stroke, the air that was drawn into the cylinder on the down stroke is being compressed. Air pressure on top of the inlet valve plus the force of its spring, returns the inlet valve to its seat. The piston continues the upward stroke and compressed air then flows by the open discharge valve, into the discharge line and on to the reservoirs (see Fig. 2). As the piston reaches the top of its stroke and starts down, the discharge valve spring and air pressure in the discharge line returns the discharge valve to its seat. This prevents the compressed air in the discharge line from returning to the cylinder bore as the intake and compression cycle is repeated.

Non-Compression of Air (Unloaded)

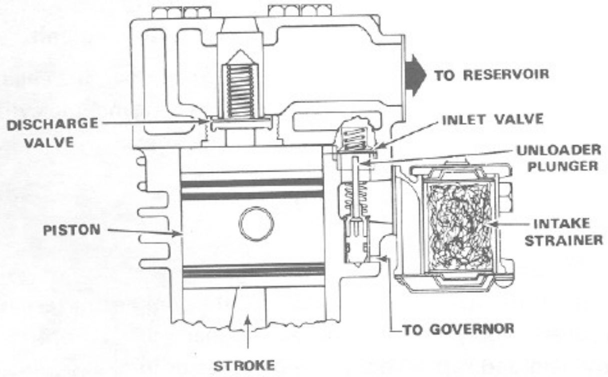
When air pressure in the reservoir reaches the cut-out setting of the governor, the governor allows air to pass from the reservoir into the cavity beneath the unloader pistons. This lifts the unloader pistons and plungers. The plungers move up and hold the inlet valves off their seats (see Fig. 3).

With the inlet valves held off their seats by the unloader pistons and plungers, air is pumped back and forth between the two cylinders. When air is used from the reservoir and the pressure drops to the cut-in setting of the governor, the governor closes and exhausts the air from beneath the unloader pistons. The unloader saddle spring forces the saddle, pistons and plungers down and the inlet valves return to their seats. Compression is then resumed.


TO RESERVOIR
INLET VALVE
DISCHARGE VALVE
UNLOADER PLUNGER
PISTON
INTAKE STRAINER
TO GOVERNOR
STROKE

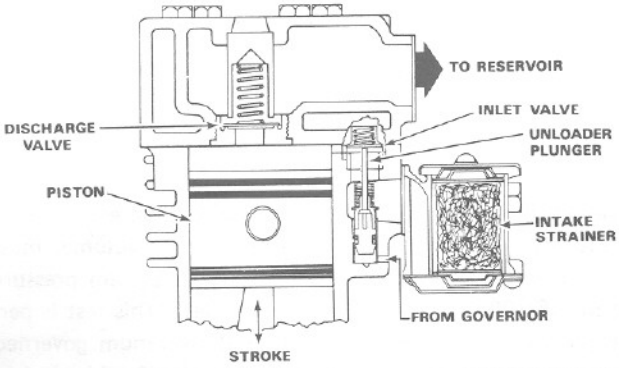
INTAKE

Fig. 1


TO RESERVOIR
INLET VALVE
DISCHARGE VALVE
UNLOADER PLUNGER
PISTON
INTAKE STRAINER
TO GOVERNOR
STROKE

COMPRESSION

Fig. 2


TO RESERVOIR
INLET VALVE
DISCHARGE VALVE
UNLOADER PLUNGER
PISTON
INTAKE STRAINER
FROM GOVERNOR
STROKE

UNLOADING

Fig. 3

Lubrication

Since all Tu-Flo 501 Compressors are connected to the engine's pressurized oil system, a continuous flow of oil is provided to the compressor, which is eventually returned to the engine.

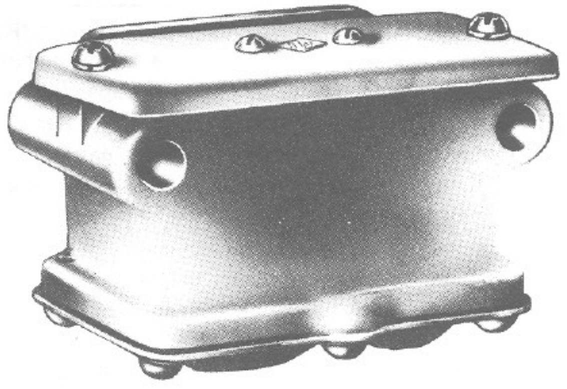
Oil is fed into the compressor in various ways, for example: through the rear end cover, the drive end of the crankshaft or through the front flange adapter. An oil passage in the crankshaft conducts pressurized oil to the precision sleeve main bearings and to the connecting rod bearings. Splash lubrication of the cylinder bores, connecting rod wrist pin bushings, and the ball type main bearings, on some models, is obtained as oil is forced out around the crankshaft journals by engine oil pressure.

Cooling

Air flowing through the engine compartment from the action of the engine's fan and the movement of the vehicle assists in cooling the crankcase. Coolant flowing from the engine's cooling system through connecting lines enters the head and passes through the head's water jacket and back to the engine. Proper cooling is important in maintaining discharge air temperatures below the maximum 400°F recommended.

PREVENTIVE MAINTENANCE

Every month, 300 operating hours or after each 10,000 miles, depending on the operating conditions, experience and the type of strainer used, service the air strainer.



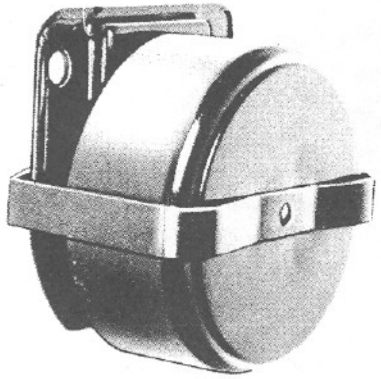
POLYURETHANE SPONGE STRAINER

Figure 4

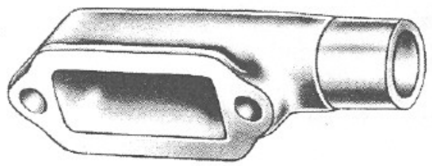
POLYURETHANE SPONGE STRAINER

EVERY 5000 MILES ON 150 OPERATING HOURS

Remove and wash all of the parts. The strainer element should be cleaned or replaced. If the element is cleaned, it should be washed in a commercial solvent or a detergent and water solution. The element should be saturated in clean engine oil, then squeezed dry before replacing it in the strainer. Be sure to replace the air strainer gasket if the entire air strainer is removed from the compressor intake.



PAPER AIR STRAINER
DRY ELEMENT-PLEATED
Figure 5



COMPRESSOR INTAKE ADAPTER
Figure 6

DRY ELEMENT – PLEATED PAPER AIR STRAINER

EVERY 20,000 MILES OR 800 OPERATING HOURS

Remove the spring clips from either side of mounting baffle and remove the cover. Replace the pleated paper filter and remount the cleaned cover making sure the filter is in position. Be sure to replace the air strainer gasket if the entire air strainer is removed from the compressor intake. (NOTE: Some compressors are fitted with compressor intake adapters which allow the compressor intake to be connected to the engine air cleaner.) In this case, the compressor receives a supply of clean air from the engine air cleaner. When the engine air filter is changed, the compressor intake adapter should be checked. If it is loose, remove the intake adapter, clean the strainer plate, if applicable, and replace the intake adapter gasket, and reinstall the adapter securely. Check line connections both at the compressor intake adapter and at the engine air cleaner. Inspect the connecting line for ruptures and replace it if necessary.

EVERY 6 MONTHS, 1800 OPERATING HOURS OR AFTER EACH 50,000 MILES

Remove the discharge head fittings and inspect the compressor discharge port and discharge line for excessive carbon deposits. If excessive buildup is noted in either, the discharge line must be cleaned or replaced and the compressor checked more thoroughly, paying special attention to the air induction system, oil supply and return system, and proper cooling. If necessary, repair or replace the compressor. Check for proper belt and pulley alignment and belt tension. Adjust if necessary, paying special attention not to over tighten the belt tension. Check for noisy compressor operation, which could indicate a worn drive gear coupling or a loose pulley. Adjust and/or replace as necessary. Check all compressor mounting bolts and retighten evenly if necessary. Check for leakage and proper unloader mechanism operation. Replace if defective in any way.

EVERY 24 MONTHS, 7200 OPERATING HOURS OR AFTER EACH 200,000 MILES

Perform a thorough inspection as indicated below and depending upon the results of this inspection or experience, disassemble the compressor, clean and inspect all parts thoroughly, repair or replace all worn or damaged parts using only genuine Bendix replacements or replace the compressor with a genuine Bendix remanufactured unit.

IMPORTANT – Should it be necessary to drain the engine cooling system to prevent damage from freezing, the cylinder head of the compressor must also be drained.

GENERAL SERVICE CHECKS

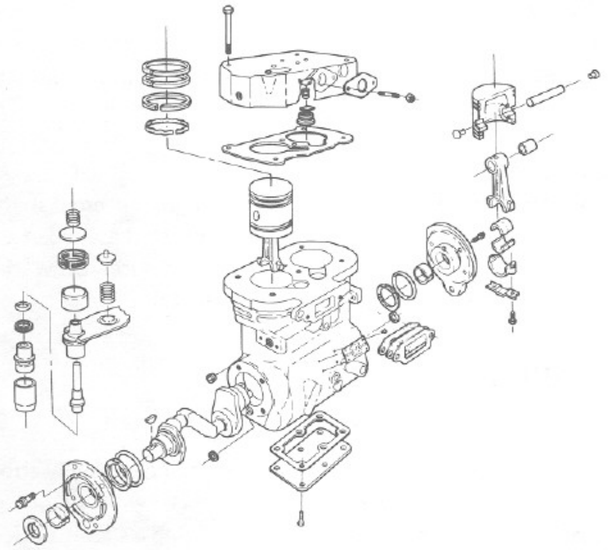
Inspection

It is of the utmost importance that the compressor receives a clean supply of air. The air strainer must be properly installed and kept clean. If the compressor intake is connected to the engine air cleaner, supercharger, etc., these connections must be properly installed and maintained. Check the compressor mountings to be sure they are secure. Check the drive for proper alignment, belt tension, etc.

Inspect the oil supply and return lines. Be sure these lines are properly installed and that the compressor is getting the proper supply of oil, and just as important, that the oil is returning to the engine. Check the coolant lines to and from the compressor and see that the cooling fins on the crankcase are not clogged with dirt, grease, etc. Check the unloader mehcanism for proper and prompt operation.

Operating Tests

Vehicles manufactured after the effective date of FMVSS 121, with the minimum required reservoir volume, must have a compressor capable of raising air system pressure from 85-100 P.S.I. in 25 seconds or less. This test is performed with the engine operating at maximum governed speed. The vehicle manufacturer must certify this performance on new vehicles with appropriate allowances for air systems with greater than the minimum required reservoir volume.



TU-FLO 501 COMPRESSOR (THRU DRIVE)
EXPLODED VIEW

Figure 7

Air Leakage Tests

Leakage past the discharge valves can be detected by removing the discharge line, applying shop air back through the discharge port and listening for escaping air. Also, the discharge valves and the unloader pistons can be checked for leakage by building up the air system until the governor cuts out, then stopping the engine. With the engine stopped, listen for escaping air at the compressor intake. To pinpoint leakage if noted, apply a small quantity of oil around the unloader pistons. If there is no noticeable leakage at the unloader pistons, the discharge valves may be leaking. If the compressor does not function as described above, or leakage is excessive, it is recommended that it be returned to the nearest authorized Bendix Distributor for a factory remanufactured compressor. If this is not possible, the compressor can be repaired using genuine Bendix replacement parts, in which case, the following information should prove helpful.

REMOVING AND DISASSEMBLY

Removing

These instructions are general and are intended to be a guide, in some cases additional preparations and precautions are necessary. Chock the wheels of the vehicle and drain the air pressure from all the reservoirs in the system. Drain the engine cooling system and the cylinder head of the compressor. Disconnect all air, water and oil lines leading to and from the compressor. Remove the drive gear(s) or pulley from the compressor crankshaft using a gear puller. Inspect the pulley or gear and associated parts for visible wear or damage. Since these parts are precision fitted, they must be replaced if they are worn or damaged.

DISASSEMBLY

General

Remove road dirt and grease from the exterior of the compressor with a cleaning solvent. Before the compressor is disassembled, the following items should be marked to show their relationship when the compressor is assembled. Mark both the front and rear end cover in relation to the crankcase. Mark the drive end of the crankshaft in relation to the front end cover and the crankcase. Mark the cylinder head in relation to the crankcase. Mark the base plate or base adapter in relation to the crankcase.

A convenient method to indicate the above relationship is to use a metal scribe to mark the parts with numbers or lines. Do not use a marking method that can be wiped off or obliterated during rebuilding, such as chalk. Remove all compressor attachments such as governors, air strainers or inlet fittings, discharge fittings and pipe plugs.

Cylinder Head

Remove the six cylinder head cap screws and tap the head with a soft mallet to break the gasket seal. Remove the inlet valve springs from the head and inlet valves from their guides in the crankcase. Remove inlet valve guides from around the inlet valve seats on the crankcase taking care not to damage seats. Scrape off any gasket material from the cylinder head and crankcase. Unscrew the discharge valve seats from the head and remove the discharge valves and springs. Inspect the discharge valve seats for nicks, cracks, and excessive wear and replace if necessary.

The discharge valve stops should be inspected for wear and replaced if excessive peening has occurred. To determine if excessive peening has occurred, measure the discharge valve travel. Discharge valve travel must not exceed .057 inches. To remove the discharge valve stops, support the machined surface of the cylinder head on an arbor press bed and gently press the stops from the top of the head and out the bottom. Be sure to allow sufficient clearance for the stops between the press bed and the bottom of the cylinder head. The valve stop bores in the cylinder head must be inspected for excessive scoring. A new head body must be used if scoring is excessive. Discard the inlet valves and springs, the discharge valves and springs and the discharge valve seats if defective.

Crankcase Base Plate or Adapter

Remove the cap screws securing the base plate or base adapter. Tap with soft mallet to break the gasket seal. Scrape off any gasket material from crankcase and plate or adapter.

Connecting Rod Assemblies

(Note: Before removing the connecting rods, mark each connecting rod and its cap. Each connecting rod is matched to its own cap for proper bearing fit, and these parts must not be interchanged.) Straighten the prongs of the connecting rod bolt lock strap and remove the bolts and bearing caps. Push the piston with the connecting rods attached out the top of the cylinders of the crankcase. Replace the bearing caps on their respective connecting rods. Remove the piston rings from the pistons. If the pistons are to be removed from the connecting rods, remove the wrist pin lock wires or teflon plugs and press the wrist pins from the pistons and connecting rods.

If the pistons are removed from the rod, inspect the bronze wrist pin bushing. Press out and replace the bushing if it is excessively worn. (See inspection of Parts) Discard the piston rings and the connecting rod journal bearings. Discard the wrist pin bushings if they were removed.

Crankcase

Remove the key or keys from the crankshaft and any burrs from the crankshaft where the key or keys were removed. (Note: Through Drive Compressors may have a crankshaft key at both ends.) Remove the four cap screws securing front or drive-end end cover or flange adapter. Remove the end cover, taking care not to damage the crankshaft oil seal or front main bearing, if any. Remove both of the small seal rings from the crankcase, and the O-Ring from around the front end cover. Remove the four cap screws securing the rear end cover and remove the rear end cover taking care not to damage the rear main bearing, if any. Remove both of the small seal rings from the crankcase and the O-Ring from around the end cover. If the compressor has ball type main bearings, press the crankshaft and ball bearings from the crankcase, then press the ball bearings from the crankshaft. Remove the unloader spring, spring saddle, and spring seat from the inlet cavity of the crankcase, using long nose pliers. Remove the unloader plungers and guides. Cover the inlet cavity with a shop rag and apply air pressure to the governor mounting pad unloader port to blow the unloader pistons out of their bores and into the inlet cavity.

CLEANING OF PARTS

General

All parts should be cleaned in a good commercial grade solvent and dried prior to inspection.

Cylinder Head

Remove all the carbon deposits from the discharge cavities and all the rust and scale from the cooling cavities of the cylinder head body. Scrape all the foreign matter from the body surfaces and use shop air pressure to blow the dirt particles from all the cavities.

Crankcase

Clean the carbon and dirt from the inlet and unloader passages. Use shop air pressure to blow the carbon and dirt deposits from the unloader passages.

Oil Passages

Thoroughly clean all oil passages through the crankshaft, crankcase, end covers, and base plate or base adapter. Inspect the passages with a wire to be sure. Blow the loosened foreign matter out with air pressure.

INSPECTION OF PARTS

Cylinder Head Body

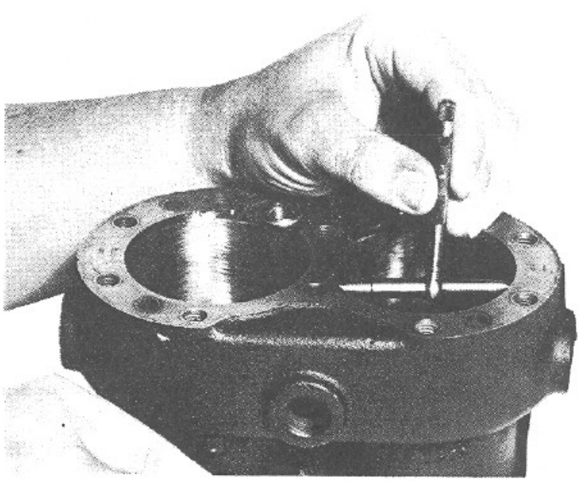
Inspect the cylinder head for cracks or damage. Apply shop air pressure to one of the coolant ports with all others plugged, and check for leakage by applying a soap solution to the exterior of the body. If leakage is detected, replace the head.

End Covers

Check for cracks and external damage. If the crankshaft main bearings are installed in the end cover, check for excessive wear and flat spots and replace them if necessary. If the compressor has an oil seal in the end cover, it should be removed by pressing it out of the end cover.

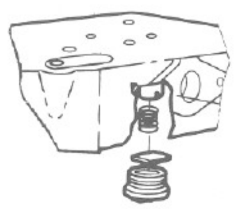
Crankcase

Check all crankcase surfaces for cracks and damage. On compressors where ball bearing main bearings are used the difference between the O.D. of the outer race and the I.D. of the crankcase hole should be .0000 in. to .0015 in. loose. This is to maintain the correct press fit. The crankcase must be replaced if the fit is too loose.



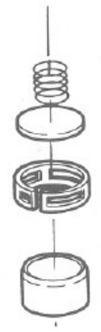
MEASURING CYLINDER BORES

Figure 8



DISCHARGE VALVE,
VALVE STOP
AND SEAT

Figure 10



INLET VALVE
AND SEAT

Figure 11

Inlet Valves and Seats

Inlet valves and springs should be replaced, if the inlet valve seats show signs of slight nicks or scratches. They can be redressed with a fine piece of emery cloth or by lapping with a lapping stone, grinding compound and grinding tool. If the seats are damaged to the extent that they cannot be reclaimed, they must be replaced. The dimension from the top of the cylinder block to the inlet valve seat should not exceed .113 in. nor be less than .101 in.

ASSEMBLY

General Note: All torques specified in this manual are **assembly** torques and can be expected to fall off after assembly is accomplished. **Do not retorque** after initial assembly torques fall.

To convert inch pounds of torque to foot pounds of torque, divide inch pounds by 12.

$$\frac{\text{inch pounds}}{12} = \text{foot pounds}$$

To convert foot pounds of torque to inch pounds of torque, multiply foot pounds by 12.

$$\text{foot pounds} \times 12 = \text{inch pounds}$$

Installing the Crankshaft

Cautionary Note:

All flange mounted compressors **must be assembled without** a gasket between the crankcase and flange adapter and some compressors do not require gaskets on the end cover. Install the new crankcase gaskets **only** where they were removed during disassembly. In service failure of the compressor will occur if gaskets are used in disregard of the preceding.

If the compressor uses a ball type main bearing, press the ball bearing onto the correct end of the crankshaft. Position the ball bearing and the crankshaft in the crankcase, making sure the drive end of the crankshaft is positioned in the crankcase as marked before disassembly. Carefully press the crankshaft and ball bearing into the crankcase using an arbor press.

In the case of compressors with a front ball bearing, place two small seal rings in the counter-sunk holes at the front of the crankcase, as well as an end cover gasket. Install the front end cover in the proper position as marked before disassembly, taking care not to damage the new oil seal.

In the case of compressors with a rear ball bearing, place two small seal rings in the counter-bore at the rear of the crankcase. In one case a gasket is used and in another a large O-Ring is placed in the counterbore at the rear of the crankcase. These are in addition to the seal rings. Install the rear end cover in the proper position as marked before disassembly. Since June, 1978, the two small seal rings have been increased slightly in cross section and a retaining ring added, as shown in Figure 12.

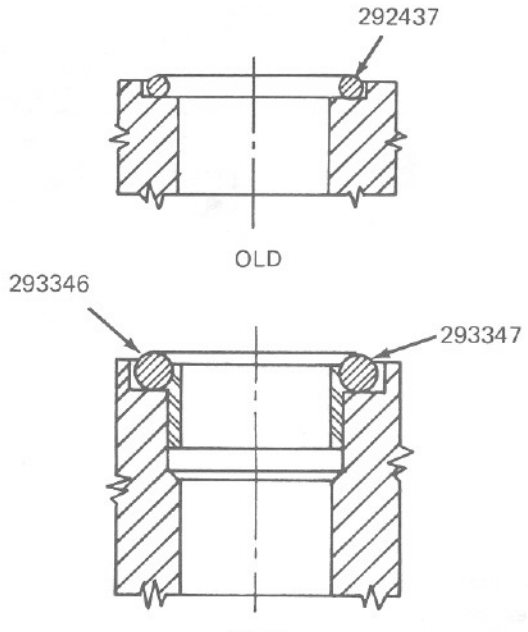
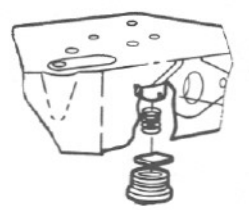


Figure 12

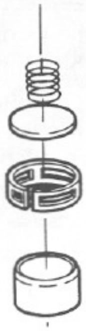
In the case of compressors with a sleeve bearing either front or rear, place the two small seal rings in the counter-sunk holes in the crankcase. **Caution**: An end cover gasket must not be used. Place the O-Ring seal in the groove around the flange adapter or the end cover, and affix the thrust washer. Install the flange adapter or end cover in the proper position as marked before disassembly, taking care not to damage the sleeve bearing.

Secure the flange adapter, front or rear end cover to the crankcase by tightening the four cap screws. See note below for torque.



DISCHARGE VALVE,
VALVE STOP
AND SEAT

Figure 10



INLET VALVE
AND SEAT

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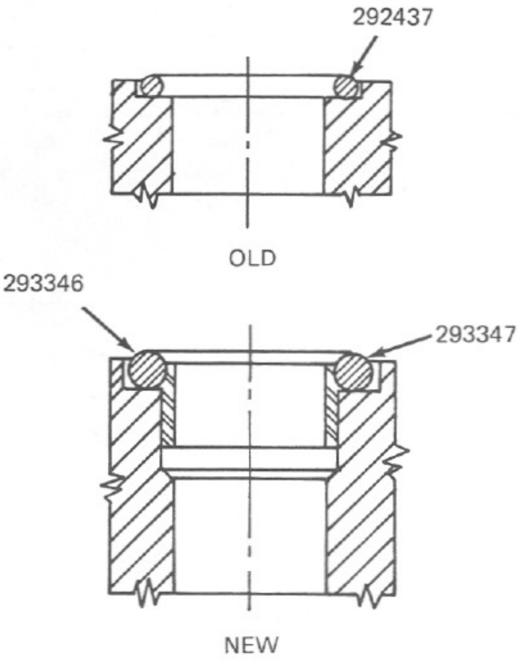


Figure 12

In the case of compressors with a sleeve bearing either front or rear, place the two small seal rings in the counter-sunk holes in the crankcase. **Caution:** An end cover gasket must not be used. Place the O-Ring seal in the groove around the flange adapter or the end cover, and affix the thrust washer. Install the flange adapter or end cover in the proper position as marked before disassembly, taking care not to damage the sleeve bearing.

Secure the flange adapter, front or rear end cover to the crankcase by tightening the four cap screws. See note below for torque.

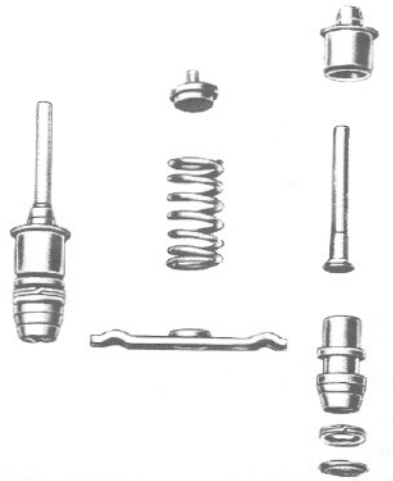
Note: For cast iron flange adapters, torque the four 7/16 in. cap screws to 38-45 foot pounds. For die cast aluminum end covers, torque the four 7/16 in. cap screws to 25-30 foot pounds. All end covers using 5/16 in. cap screws or stud and nuts are torqued to 15-18 foot pounds. For through drive compressors with a cast iron end cover, torque the four 7/16 in. cap screws to 25-30 foot pounds.

Pistons and Connecting Rods

If new wrist pin bushings are to be used, they should be pressed into the connecting rods so that the oil hole in the bushing lines up with the one in the rod. The new bushings should then be reamed or honed to provide between .0001 in. (.00254 mm) and .0006 in. (.01524 mm) clearance on the wrist pin. Position the connecting rod in the piston and press in the wrist pin.

Pistons installed in compressors manufactured prior to November, 1976, will have the wrist pin secured in the piston by a lock wire extending through matching holes in wrist pin and piston boss, anchored in a hole in the side wall of the piston. If the original pistons are used the wrist pin must be pressed in so the hole in the wrist pin aligns with that of the piston and secure same by inserting the new lockwire through the hole in piston and wrist pin and lock the wire by snapping the short 90° section into the lockwire hole in the bottom of the piston.

Compressors built after November, 1976, will have the wrist pin secured by Teflon buttons in either end of the wrist pin, allowing the wrist pin to float. The Teflon buttons pc. no. 292392 may be used with either new or old wrist pins. The later design pistons have two rings above the wrist pin and one below. Install the piston rings in the correct location with the ring pipmarks up. Stagger the position of the ring gaps. Prelubricate the piston, piston rings, wrist pins and connecting rod.



UNLOADER MECHANISM
Figure 13

Unloader

A new unloader kit should be used when rebuilding. (Figure 13). (Piece Number 279615). The unloader pistons in the kit are prelubricated with a special lubricant piece number 239379 and need no additional lubrication. Install the unloader pistons in their bores being careful not to cut the o-rings or distort the back-up rings. Position the unloader plungers in their guides and slip them in and over the tops of the pistons. Install the unloader spring seat in the crankcase inlet cavity; a small hole is drilled in the crankcase for this purpose. Position the saddle between the unloader piston guides, so its forks are centered on the guides. Install the unloader spring, making sure it seats over the spring seats both in the crankcase and on the saddle. Position and install the inlet valve guides, then drop the inlet valves in their guides. The inlet valves should be a loose sliding fit in the guides.

Cylinder Head

Install the inlet valve springs in the cylinder head by applying a turning motion to the spring after it is in the head. The turning motion should dig the spring wire into the spring seat in the bottom of the spring bore in the head. Should this procedure fail after repeated attempts, use a very small quantity of grease to hold them in place, just enough to keep the springs from falling out. Place the cylinder head gasket on the cylinder block. Carefully align the cylinder head assembly on the block and install the cap screws, tightening them evenly to a torque of 25-30 foot pounds.

Base Plate or Base Adapter

Position the base plate or base adapter gasket on the crankcase and install the base plate or base adapter as marked before disassembly. Tighten the six cap screws securing the cast iron base adapter evenly to a torque of 38-45 foot pounds, and 12-16 foot pounds for base plate or aluminum cover.

Testing Rebuilt Compressor

In order to properly test a compressor under operating conditions, a test rack for correct mounting, cooling, lubricating, and driving the compressor is necessary. Such tests are not compulsory if the unit has been carefully rebuilt by an experienced person. A compressor efficiency or build-up test can be run which is not too difficult. An engine lubricated compressor must be connected to an oil supply line of at leat 15 P.S.I. pressure during the test and an oil return line must be installed to keep the crankcase drained.

Connect to the compressor discharge port, a reservoir with a volume of 1500 cubic inches, including the volume of connecting line. With the compressor operating at 2100 R.P.M., the time required to raise the reservoir(s) pressure from 85 P.S.I. to 100 P.S.I. should not exceed 7 seconds. During this test, the compressor should be checked for gasket leakage and noisy operation, as well as unloader operation and leakage.

TROUBLE SHOOTING

The following is a listing of the most commonly experienced compressor deficiencies and their probable causes.

Excessive build-up and recovery time:

1. Dirty intake strainer.
2. Restriction in the compressor inlet or discharge lines or cavities.
3. Leaking or broken discharge valves.
4. Drive belt slipping.
5. Inlet valves worn excessively or stuck open.
6. Excessive air system leakage.
7. Excessive wear on piston rings and/or cylinders.

Noisy compressor operation:

1. Loose drive gear or pully.
2. Excessively worn drive coupling.
3. Worn or burned out bearings.
4. Excessive wear.
5. Improper lubrication to the compressor.
6. Restrictions in the cylinder head or discharge line.

Excessive oil passage:

1. Dirty air strainer.
2. A small, kinked, or restricted oil return line.
3. Back pressure from the engine crankcase.
4. High inlet vacuum at the compressor.
5. Defective oil seal or oil seal ring in the end cover(s).
6. Piston rings improperly installed.
7. Excessive ring or cylinder wear.

Compressor fails to unload:

1. Defective or worn unloader pistons or bores.
2. Defective governor.
3. Unloader line from governor kinked or the cavity beneath the unloader pistons restricted.
4. Unloader mechanism binding or kinked.

INSPECTION OF REBUILT UNIT

Check to be sure that covers, plugs, or masking tape are used to protect all ports if compressor is not to be installed immediately. Fit the end of all crankshafts with keys, nuts, and cotter pins as required and then protect the ends against damage by wrapping with masking tape or friction tape. The open bottom of a vertical engine lubricated compressors should be protected against the entrance of dirt during handling or storage, by installing a temporary cover over the base.

TABULATED DATA

Number of cylinders	2
Bore size	2.625 in.
Stroke	1.50 in.
Piston displacement at 1250 RPM	12 cu. ft.
Piston displacement per revolution	16.5 cu. in.
Maximum recommended RPM (naturally aspirated)	3000
Minimum coolant flow at maximum RPM	2.5 gal./min.
Horsepower required at 3000 RPM against 100 PSI head pressure	4.9 H.P.
Recommended minimum discharge line size	5/8 in. OD Copper Tube
Recommended minimum oil return line size	5/8 in. OD Tubing
Recommended minimum oil supply line size	1/4 in. OD Tubing
Recommended minimum unloader line size	1/4 in. OD Tubing
Recommended minimum inlet cavity line size (when compressor is connected to engine air cleaner)	5/8 in. ID minimum
Recommended minimum coolant line size	1/2 in. OD Tubing
Recommended maximum inlet air temperature	250°F
Recommended maximum discharge air temperature	400°F
Minimum pressure required to unload	60 PSI

COMPLETE FIELD MAINTENANCE KIT NO 287043

Contents of this kit as follows:

1	Unloader mechanism kit
2	Inlet valve guides
2	Inlet valves
2	Inlet valve springs
1	Cylinder head gasket
2	Discharge valves
2	Discharge valve springs
1	Discharge flange gasket
1	Inlet flange gasket
1	Governor flange gasket
1	Filter element
1	Instruction sheet

UNLOADER KIT NO 279615

Contents of this kit as follows:

2	Plungers
2	Guides
2	Pistons with O-Ring seals and backup rings
1	Spring and one Spring Saddle

The above parts are pre-packed and lubricated.

Bendix

Heavy Vehicle Systems Group

Service Data

SD-01-5

TU-FLO 700 AIR COMPRESSOR

DESCRIPTION

The function of the air compressor is to provide and maintain air under pressure to operate devices in the air brake and/or auxiliary air systems.

The Tu-Flo 700 is a two cylinder single stage, reciprocating compressor with a rated displacement of 15.5 cubic feet of air per minute at 1250 rpm.

The compressor assembly is comprised of three cast iron major sub-assemblies; the cylinder head, the cylinder block and the crankcase.

The cylinder head houses the discharge valving and is installed to the cylinder block. The cylinder block houses the cylinder bores and inlet valves and is installed to the crankcase. The crankcase houses the crankshaft and main bearings.

The Tu-Flo 700 compressor is available in various mounting and drive configurations as required by engine designs. Two (2) convenient governor mounting pads are provided on the block.

The cylinder head and block are cooled by coolant routed to the compressor from the engine cooling system.

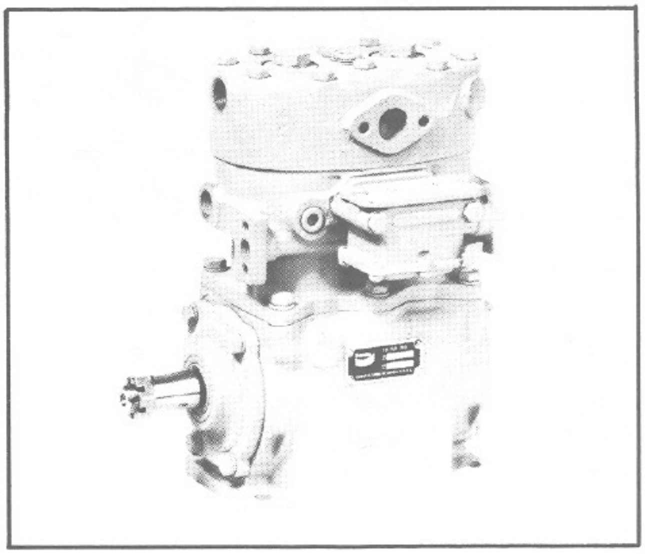
Lubrication for the internal parts of the Tu-Flo 700 compressor is provided by the engine's pressurized oil system.

A nameplate, identifying the compressor piece number and serial number, is attached to the side of the crankcase. A nameplate with a black background denotes a new compressor and a red background designates a factory remanufactured unit.

OPERATION

The compressor is driven by the vehicle engine and is operating continuously while the engine is running. Actual compression of air is controlled by the compressor unloading mechanism and the governor. The governor is generally mounted on the compressor and maintains the brake system air pressure to a preset maximum and minimum pressure level.

INTAKE AND COMPRESSION OF AIR (LOADED)



During the down stroke of the piston, a slight vacuum is created between the top of the piston and the head, causing the inlet valve to move up and off its seat. (Note: The discharge valve remains on its seat.) Atmospheric air is drawn through the air strainer by the open inlet valve and into the cylinder (see Fig. 1). As the piston begins its upward stroke, the air that was drawn into the cylinder on the down stroke is being compressed. Air pressure on top of the inlet valve plus the force of the inlet spring, returns the inlet valve to its seat. The piston continues the upward stroke and compressed air then flows by the open discharge valve, into the discharge line and on to the reservoirs (see Fig. 2). As the piston reaches the top of its stroke and starts down, the discharge valve spring and air pressure in the discharge line returns the discharge valve to its seat. This prevents the compressed air in the discharge line from returning to the cylinder bore as the intake and compression cycle is repeated.

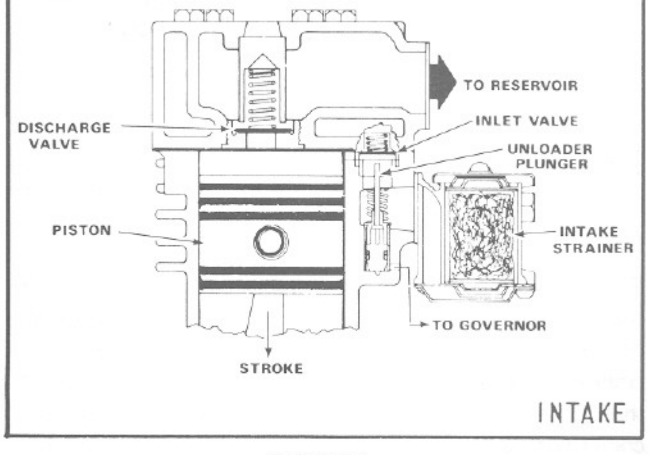


FIGURE 1

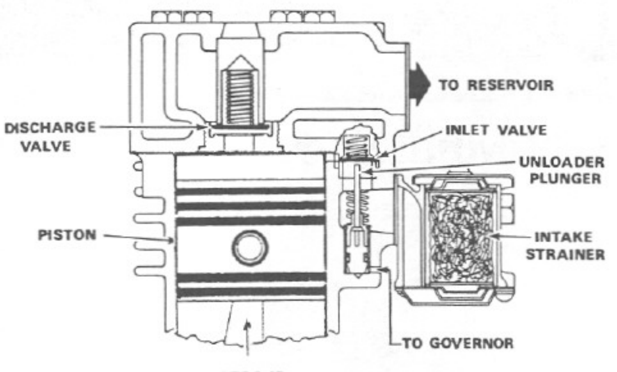


FIGURE 2 COMPRESSION

NON-COMPRESSION OF AIR (UNLOADED)

When air pressure in the reservoir reaches the cut-out setting of the governor, the governor allows air to pass from the reservoir, through the governor and into the cavity beneath the unloader pistons. This lifts the unloader pistons and plungers. The plungers move up and hold the inlet valves off their seats (see Fig. 3).

With the inlet valves held off their seats by the unloader pistons and plungers, air is pumped back and forth between the two cylinders. When air is used from the reservoir and the pressure drops to the cut-in setting of the governor, the governor closes and exhausts the air from beneath the unloader pistons. The unloader saddle spring forces the saddle, pistons and plungers down and the inlet valves return to their seats. Compression is then resumed.

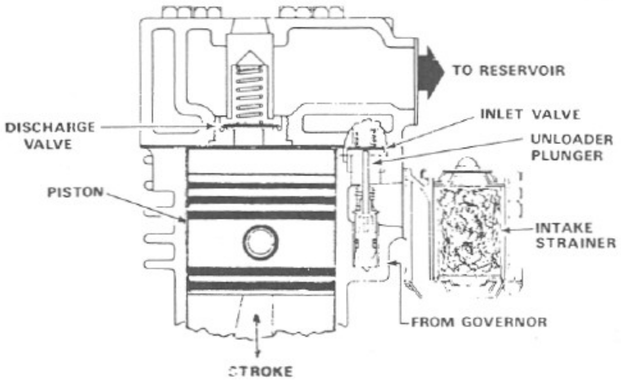


FIGURE 3 UNLOADING

LUBRICATION

The vehicle's engine provides a continuous supply of oil to the compressor. Oil is routed from the engine to the compressor oil inlet. An oil passage in the compressor crankshaft allows oil to lubricate the connecting rod crankshaft bearings. Connecting rod wrist pin bushings and crankshaft ball bearings are splash lubricated. An oil return line connected from the compressor drain outlet to the vehicle engine crankcase allows for oil return.

COOLING

Air flowing through the engine compartment from the action of the engine's fan and the movement of the vehicle assists in cooling the crankcase. Coolant flowing from the engine's cooling system through connecting lines enters the compressor and flows through the internal passages in the cylinder block and head and is returned back to the engine. Proper cooling is important in maintaining discharge air temperatures below the maximum recommended 400°F.

PREVENTIVE MAINTENANCE

Depending upon the type air strainer and on the operating conditions and experience, service the air strainer as follows:

Sponge type:	Clean or replace element every 5000 miles or 150 operating hours.
Paper Element:	Replace every 20,000 miles or 800 operating hours

POLYURETHANE SPONGE STRAINER

Remove and wash all of the parts. The strainer element should be cleaned or replaced. If the element is cleaned, it should be washed in a commercial solvent or a detergent and water solution. The element should be saturated in clean enigne oil, then squeezed dry before replacing it in the strainer. Be sure to replace the air strainer gasket if the entire air strainer is removed from the compressor intake.

DRY ELEMENT – PLEATED PAPER AIR STRAINER

Remove the spring clips from either side of mounting baffle and remove the cover. Replace the pleated paper filter and remount the cleaned cover, making sure the filter is in position. Be sure to replace the air strainer gasket if the entire air strainer is removed from the compressor intake.

NOTE: Some compressors are fitted with compressor intake adapters, which allow the compressor intake to be connected to the engine air cleaner. In this case, the compressor receives a supply of clean air from the engine air cleaner. When the engine air filter is changed, the compressor intake adapter should be checked. If it is loose, remove the intake adapter, clean the strainer plate, if applicable, and replace the intake adapter gasket, and reinstall the adapter securely. Check line connections both at the compressor intake adapter and at the engine air cleaner. Inspect the connecting line for ruptures and replace it if necessary.

EVERY 6 MONTHS, 1800 OPERATING HOURS OR AFTER EACH 50,000 MILES

Remove the discharge fittings and inspect the compressor discharge port and discharge line for excessive carbon deposits. If excessive buildup is noted in either, the discharge line must be cleaned or replaced and the compressor checked more thoroughly. Carefully inspect the air induction system, oil supply and return system. If necessary, repair or replace the compressor. Depending upon type of drive, check for proper belt and pulley alignment and belt tension. Adjust if necessary, paying special attention not to over-tighten the belt tension. Check for noisy compressor operation, which could indicate a worn drive gear coupling or a loose pulley. Adjust and/or replace as necessary. Check all compressor mounting bolts and retighten evenly if necessary. Check for leakage and proper unloader mechanism operation. Repair or replace parts as necessary.

EVERY 24 MONTHS, 7200 OPERATING HOURS OR AFTER EACH 200,000 MILES

Perform a thorough inspection, and depending upon the results of this inspection or experience, disassemble the compressor, clean and inspect all parts thoroughly, repair or replace all worn or damaged parts using only genuine Bendix replacements or replace the compressor with a genuine Bendix remanufactured unit.

IMPORTANT: Should it be necessary to drain the engine cooling system to prevent damage from freezing, the cylinder head of the compressor must also be drained.

GENERAL SERVICE CHECKS

INSPECTION

It is of the utmost importance that the compressor receives a clean supply of air. The air strainer must be properly installed and kept clean. If the compressor intake is connected to the engine air cleaner, this connection must be properly installed and maintained. Check the compressor mountings to be sure they are secure. Check the drive for proper alignment, belt tension, etc.

Inspect the oil supply and return lines. Be sure these lines are properly installed and that the compressor is getting the proper supply of oil, and just as important, that the oil is returning to the engine. Check the coolant lines to and from the compressor. Check the unloader mechanism for proper operation.

OPERATING TESTS

Vehicles manufactured after the effective date of FMVSS 121, with the minimum required reservoir volume, must have a compressor capable of raising air system pressure from 85-100 psi in 25 seconds or less. This test is performed with the engine operating at maximum recommended governed speed. The vehicle manufacturer must certify this performance on new vehicles with appropriate allowances for air systems with greater than the minimum required reservoir volume.

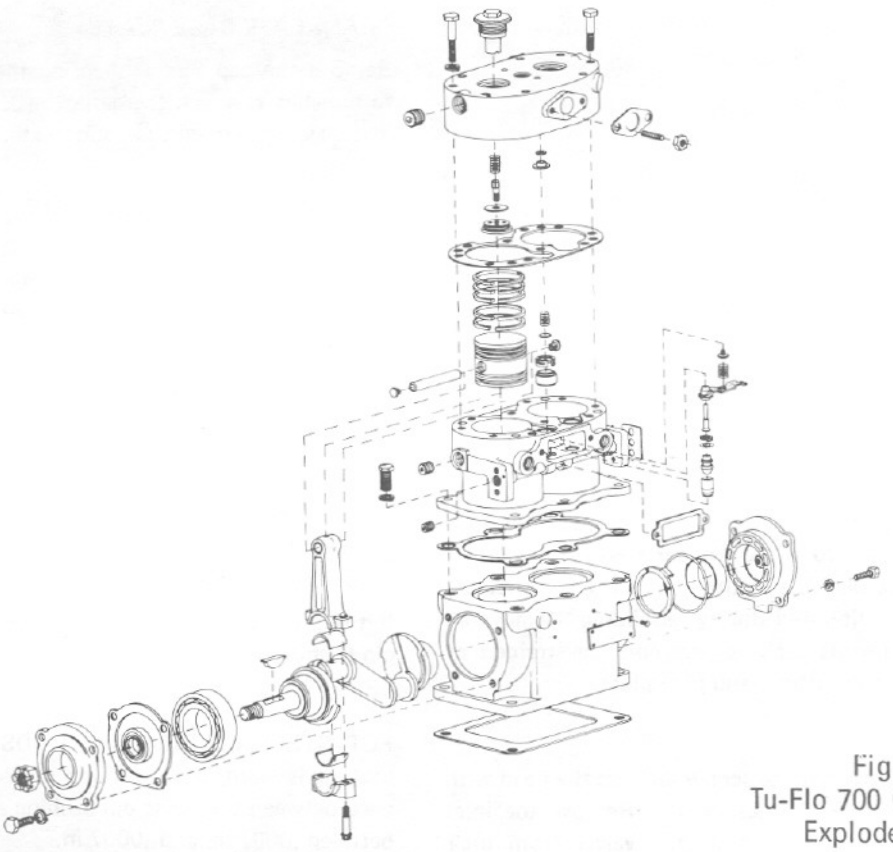


Fig. 4
Tu-Flo 700 Compressor
Exploded View

AIR LEAKAGE TESTS

Leakage past the discharge valves can be detected as follows: Remove the discharge line and cylinder head from the compressor and apply shop air back through the discharge port. Coat the discharge valve seats with soapsuds. Bubble leakage is permitted.

The unloader pistons can be checked for leakage as follows: Build up the air system to governor cut-out and shut off engine. Listen for escaping air at the compressor intake. To pinpoint leakage, apply a small amount of oil around the unloader pistons. No leakage permitted.

If the compressor does not function as described above, or leakage is excessive, it is recommended that it be returned to the nearest authorized Bendix distributor for a factory remanufactured compressor. If this is not possible, the compressor can be repaired using genuine Bendix replacement parts, in which case, the following information should prove helpful.

REMOVING AND DISASSEMBLY

REMOVING

These instructions are general and are intended to be a guide; in some cases additional preparations and precautions are necessary. Chock the wheels of the vehicle and drain the air pressure from all the reservoirs in the system. Disconnect all air, water, and oil lines leading to and from the compressor. Remove the drive gear(s) or pulley from the compressor crankshaft using a gear puller. Inspect the pulley or gear and associated parts for visible wear or damage. Since these parts are precision fitted, they must be replaced if they are worn or damaged.

DISASSEMBLY

GENERAL

Remove road dirt and grease from the exterior of the compressor with a cleaning solvent. Before the compressor is disassembled, the following items should be marked to show their relationship when the compressor is assembled. Mark both the front and rear end cover in relation to the crankcase. Mark the drive end of the crankshaft in relation to the front end cover and the crankcase. Mark the cylinder head in relation to the block and the block in relation to the crankcase. Mark the base plate or base adapter in relation to the crankcase.

A convenient method to indicate the above relationships is to use a metal scribe to mark the parts with numbers or lines. Do not use a marking method such as chalk that can be wiped off or obliterated during rebuilding. Remove all compressor attachments such as governors, air strainers or inlet fittings, discharge fittings and pipe plugs.

CYLINDER HEAD

Remove the cylinder head cap screws and tap the head with a soft mallet to break the gasket seal. Remove the inlet valve springs from the head and inlet valves from their guides in the block. Scrape off any gasket material from the cylinder head and block. Unscrew the discharge valve seat from the head and remove the springs, guide and discharge valve. Inspect the discharge valve seats for nicks, cracks, and excessive wear, and replace if necessary. The discharge valve cap nut/stop should be removed and inspected for wear and replaced if excessive peening has occurred. To determine if excessive peening has occurred, measure the discharge valve travel. Discharge valve travel must not exceed .046 in. If discharge travel is excessive, replace cap nut/stop assembly, discharge valve and spring.

CYLINDER BLOCK

If compressor is fitted with an air strainer, inlet elbow or governor, remove same.

Remove cap screws securing cylinder block to crankcase; separate crankcase and cylinder block and scrape off gasket.

Remove unloader spring, spring saddle and spring seat from cylinder block.

Remove unloader guides and plungers and with the use of shop air blow unloader pistons out of cylinder block unloader piston bores.

Remove inlet valve guides; inlet valve seats can be removed but only if they are worn or damaged and are being replaced. Unloader bore bushings should be inspected but not removed unless they are damaged. If bushings are to be replaced, they can be removed by running a 1/8 in. pipe threaded rod and pulling the bushing straight up and out. Do not use an "easy-out" for removing the bushings.

CRANKCASE BASE PLATE

Remove the cap screws securing the base plate. Tap with soft mallet to break the gasket seal. Scrape off any gasket material from crankcase and plate.

CONNECTING ROD ASSEMBLIES

NOTE: Before removing the connecting rods, mark each connecting rod and its cap. Each connecting rod is matched to its own cap for proper bearing fit, and these parts must not be interchanged.

Remove the bolts and bearing caps. Push the piston with the connecting rods attached out the top of the cylinders of the block. Replace the bearing caps on their respective connecting rods. Remove the piston rings from the pistons. If the pistons are to be removed from the connecting rods, remove the teflon buttons and press the wrist pins from the pistons and connecting rods.

If the pistons are removed from the rod, inspect the wrist pin bushing.

FOR STEEL CONNECTING RODS ONLY – if wrist pin bushing is worn, press out and replace. Ream so that clearance between the wrist pin bushing and wrist pin should be between .0002 in. and .0007 in.

FOR ALUMINUM CONNECTING RODS ONLY – if wrist pin bushing is worn, discard rod assembly and replace with a new connecting rod assembly.

CRANKCASE

Remove the key or keys from the crankshaft and any burrs from the crankshaft where the key or keys were removed. (NOTE: Through drive compressors may have a crankshaft key at both ends.) Remove the end cover(s), taking care not to damage the crankshaft oil seal or front main bearing, if any. Remove end cover gasket(s) and oil seal(s). Replace oil seal after cleaning end cover(s). Press the crankshaft and bearings from crankcase, and press bearings from crankshaft.

CLEANING OF PARTS

GENERAL

All parts should be cleaned in a good commercial grade solvent and dried prior to inspection.

CYLINDER HEAD

Remove all the carbon deposits from the discharge cavities and all the rust and scale from the cooling cavities of the cylinder head body. Scrape all the foreign matter from the body surfaces and use shop air pressure to blow the dirt particles from all the cavities.

CYLINDER BLOCK

Clean the carbon and dirt from the inlet and unloader passages. Use shop air pressure to blow the carbon and dirt deposits from the unloader passages.

OIL PASSAGES

Thoroughly clean all oil passages through the crankshaft, crankcase, end covers, and base plate or base adapter. Inspect the passages with a wire to be sure they are clear. Blow the loosened foreign matter out with air pressure.

INSPECTION OF PARTS

CYLINDER HEAD BODY

Inspect the cylinder head for cracks or damage. Apply shop air pressure to one of the coolant ports with all others plugged, and check for leakage by applying a soap solution to the exterior of the body. If leakage is detected, replace the head.

END COVERS

Check for cracks and external damage. If the crankshaft main bearings (sleeve) are installed in the end cover, check for excessive wear and flat spots and replace them if necessary. If the compressor has an oil seal in the end cover, it should be removed by pressing it out of the end cover.

CRANKCASE

Check all crankcase surfaces for cracks and damage. On compressors where ball bearing main bearings are used, the difference between the O.D. of the outer race and the I.D. of the crankcase hole should be .0000 in. to .0015 in. loose. This is to maintain the correct press fit. The crankcase must be replaced if the fit is too loose.

On compressors fitted with precision, sleeve main bearings, the difference between the O.D. of the crankshaft journal and the main bearing I.D. must not exceed .005 in. If the clearance is greater than .005 in., the end cover or main bearing must be replaced.

CYLINDER BLOCK

Check the unloader bore bushings to be sure they are not worn, rusted, or damaged. If these bushings are to be replaced, they can be removed by running a 1/8 in. pipe thread tap into the bushings, and inserting a 1/8 in. pipe threaded rod and pulling the bushing straight up and out. Do not use an "easy-out" for removing these bushings. If the inlet valve seats are worn or damaged, so they cannot be reclaimed by facing, they should be replaced. Cylinder bores which are scored or out of round by more than .001 in. should be rebored or honed oversize. Oversized pistons and piston rings are available in .010 in., .020 in. and .030 in. oversizes. Cylinder bores must be smooth, straight and round. Clearance between the cast iron pistons and cylinder bores should be between .002 in. minimum and .004 in. maximum.

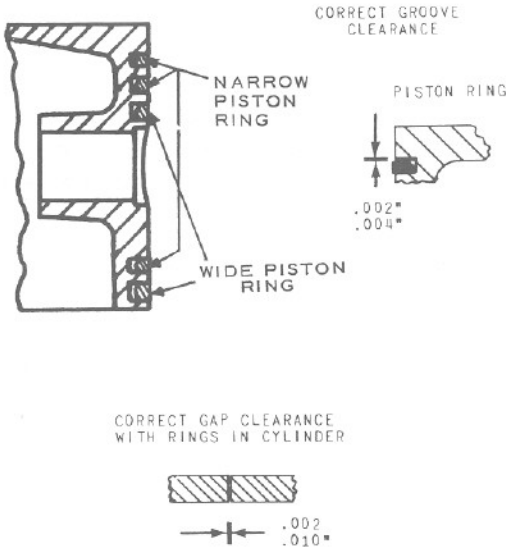


FIGURE 5

PISTONS

Check the pistons for scores, cracks, or enlarged ring grooves; replace the pistons if any of these conditions are found. Measure each piston with a micrometer in relation to the cylinder bore diameter to be sure the diametral clearance is between .002 in. minimum and .004 in. maximum.

Check the fit of the wrist pins to the pistons and connecting rod bushings. The wrist pin should be a light press fit in the piston. If the wrist pin is a loose fit, the piston and pin assembly should be replaced. Check the fit of the wrist pin in the connecting rod bushing by rocking the piston. This clearance should not exceed .0007 in.. If excessive clearance is found:

FOR STEEL CONNECTING RODS ONLY – press out wrist pin and replace. Ream so that clearance between wrist pin bushing and wrist pin should be between .0002 in. and .0007 in.

FOR ALUMINUM CONNECTING RODS ONLY – discard rod assembly and replace with a new connecting rod assembly.

Check the fit of the piston rings in the piston ring grooves. Check the ring gap with the rings installed in the cylinder bores. Refer to Fig. 5 for correct gap and groove clearance.

CRANKSHAFT

Check the crankshaft threads, keyways, ends and all machined and ground surfaces for wear, scores, or damage. Standard crankshaft journals are 1.1250 in.-1.1242 in. in diameter. If the crankshaft journals are excessively scored or worn, or out of round, the crankshaft must be replaced. Connecting rod bearing inserts are available in .010 in., .020 in., and .030 in. undersizes for compressors with reground crankshafts.

FOR BALL BEARINGS – main bearing journals must be maintained so ball bearings are a snug fit. If snug fit does not exist, the crankshaft should be replaced.

FOR SLEEVE BEARINGS – clearance between crankshaft journal must not exceed .005 in. If clearance is excessive, the sleeve bearing and crankshaft should be replaced with appropriate undersize parts.

If crankshafts are fitted with oil seal rings, the oil seal ring groove or grooves must not be worn. The ring groove walls must have a good finish and they must be square. Check to be sure the oil passages are open through the crankshaft.

CONNECTING ROD BEARINGS

Used bearing inserts must be replaced. Connecting rod caps are not interchangeable. The locking slots of the connecting rod and cap should be positioned adjacent to each other. Clearance between the connecting rod journal and the connecting rod bearing must not be less than .0003 in. or more than .0021 in. after rebuilding.

REPAIRS

DISCHARGE VALVES, VALVE STOPS AND SEATS

If the discharge valve seats merely show signs of slight wear, they can be dressed by using a lapping stone, grinding compound and grinding tool. Install the new discharge valve springs and valves. Screw in the discharge valve seats. Discharge valve travel should be between .030 in. to .046 in.

To test for leakage by the discharge valves, apply 100 psi to the cylinder head discharge port and apply a soap solution to the discharge valves and seats. Leakage in the form of soap bubbles is permissible. If excessive leakage is found, leave the air pressure applied and with the use of a fibre or hardwood dowel and a hammer, tap the discharge valves off their seats several times. This will help the valves to seat and should reduce the leakage. With the air pressure still applied at the discharge port of the cylinder head, check for leakage around the discharge valve cap nut on the top of the cylinder head casting. No leakage is permitted.

INLET VALVES AND SEATS

Inlet valves and springs should be replaced. If the inlet valve seats show signs of slight nicks or scratches, they can be redressed with a fine piece of emery cloth or by lapping with a lapping stone, grinding compound and grinding tool. If the seats are damaged to the extent that they cannot be reclaimed, they must be replaced. The dimension from the top of the cylinder block to the inlet valve should not exceed .113 in. nor be less than .101 in.

ASSEMBLY

GENERAL NOTE: All torques specified in this manual are assembly torques and typically can be expected to fall off after assembly is accomplished. DO NOT RE-TORQUE after initial assembly torques fall.

To convert inch pounds of torque to foot pounds of torque, divide inch pounds by 12.

$$\frac{\text{inch pounds}}{12} = \text{foot pounds}$$

To convert foot pounds of torque to inch pounds of torque, multiply foot pounds by 12.

$$\text{foot pounds} \times 12 = \text{inch pounds}$$

INSTALLING CRANKSHAFT

If the crankshaft is fitted with oil seal rings, install rings. Position ball bearing(s) and crankshaft in crankcase, making certain the drive end of the crankshaft is positioned in the crankcase as marked before disassembly.

If one end of the crankcase is counterbored for a ball bearing, make certain the crankshaft is installed through the correct end of the crankcase. Carefully press the crankshaft and bearings into the crankcase.

Position a new rear end cover gasket over the rear end of the crankcase, making certain the oil hole in the gasket lines up with the oil hole in the crankcase. Install end cover with oil seal ring (if used) on crankcase. The end cover should be positioned correctly in relation to the oil holes in the gasket and crankcase. Install cap screws with lock washers and torque to 175-225 inch pounds.

If the opposite end cover requires an oil seal, the new seal should be pressed into the end cover. Install a new end cover gasket and carefully install end cover over crankshaft and to crankcase to avoid damage to seal. Install cap screws and lock washers and torque to 175-225 inch pounds.

PISTONS AND CONNECTING RODS

If new wrist pin bushings are to be used (steel rods only) they should be pressed into the connecting rods so that the oil hole in the bushing lines up with the one in the rod. The new bushings should then be reamed or honed to provide between .0002 in. and .0007 in. clearance on the wrist pin. Position the connecting rod in the piston and install a teflon button on each side of the piston. Install the piston rings in the correct location with the ring pip-marks up. Stagger the position of the ring gaps. Prelubricate the piston, piston rings, wrist pin, and connecting rod bearings with clean engine oil before installing them in the compressor. Remove the connecting bolts and bearing and bearing cap from one connecting rod. Turn the crankshaft so that one of its connecting rod journals is in the downward, center position. Install the crankshaft journal bearing segments in the connecting rod and connect the rod cap. Insert the connecting rod with piston through the top of the cylinder. Position and attach the bearing cap to the connecting rod. Tighten the connecting rod bolts evenly and torque to 125-140 inch pounds. Install the other connecting rod and piston in the same manner. It is recommended that new connecting rod cap screws be used.

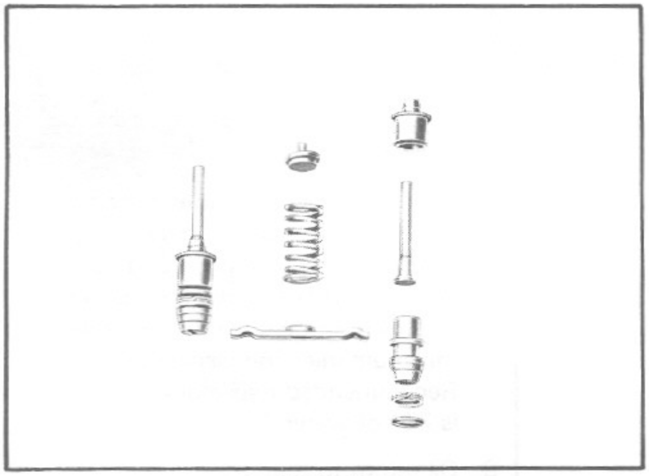


FIGURE 6

UNLOADER

A new unloader kit should be used when rebuilding (piece number 279615). The unloader pistons in the kit are prelubricated with a special lubricant (piece number 239379) and do not require additional lubrication. Install the unloader pistons in their bores, being careful not to cut the O-Rings or distort the back-up rings. Position the unloader plungers in their guides and slip them in and over the tops of the pistons. Install the unloader spring seat in the cylinder block inlet cavity; a small hole is drilled in the block for this purpose. Position the saddle between the unloader piston guides, so its forks are centered on the guides. Install the unloader spring, making sure it seats over the spring seats both in the block and on the saddle. Position and install the inlet valve guides, then drop the inlet valves in their guides. There should be a loose sliding fit between the guides and valves.

CYLINDER HEAD

Install the inlet valve springs in the cylinder head by applying a turning motion to the spring after it is in the head. The turning motion should dig the spring wire into the spring seat in the bottom of the spring bore in the head. Should this procedure fail after repeated attempts, use a very small quantity of grease to hold them in place (just enough to keep the springs from falling out). Place the cylinder head gasket on the cylinder block. Carefully align the cylinder head assembly on the block and install the cap screws, tightening them evenly to a torque of 175-225 inch pounds.

BASE PLATE

Position the base plate gasket on the crankcase and install the base plate or base adapter as marked before disassembly. Tighten cap screws securing the base plate to a torque of:

1/4 - 20 hex hd. - 85 to 115 inch pounds
5/16 - 18 hex hd - 95 to 125 inch pounds

TESTING REBUILT COMPRESSOR

In order to properly test a compressor under operating conditions, a test rack for correct mounting, cooling, lubricating, and driving the compressor is necessary. Such tests are not compulsory if the unit has been carefully rebuilt by an experienced person. A compressor efficiency or build-up test can be run as follows: An engine lubricated compressor must be connected to an oil supply line of at least 15 pounds pressure during the test and an oil return line must be installed to keep the crankcase drained.

Connect to the compressor discharge port, a reservoir with a volume of 1500 cubic inches, including the volume of connecting line. With the compressor operating at 2100 rpm, the time required to raise the reservoir pressure from 85 psi to 100 psi should not exceed 5 seconds. During this test, the compressor should be checked for gasket leakage and noisy operation, as well as unloader operation and leakage.

INSPECTION OF REBUILT UNIT

Check to be sure that covers, plugs, or masking tape are used to protect all ports if compressor is not to be installed immediately. Fit the end of all crankshafts with keys, nuts, and cotter pins as required and then protect the ends against damage by wrapping with masking tape or friction tape. The open bottom of a vertical engine lubricated compressor should be protected against the entrance of dirt during handling or storage, by installing a temporary cover over the base.

TU-FLO 700 COMPRESSOR

SPECIFICATIONS

Number of cylinders	2
Bore size	2.75"
Stroke	1.81"
Displacement @ 1250 RPM	15.5 CU. FT.
Maximum recommended RPM	3000
Minimum coolant flow at maximum RPM	2.5 GAL/MIN.
Recommended maximum inlet temp.	250° F
Recommended maximum discharge temp.	400° F
Minimum pressure required to unload	60 PSI
Recommended air induction	naturally aspirated only
Weight	46 lbs. (approx.)

RECOMMENDED CONNECTING LINE SIZES

Discharge line	5/8" O.D. Min. copper tube
Inlet line (when connected to engine air cleaner)	5/8" I.D. Min.
Oil supply line	1/4" O.D. tubing
Oil return line	5/8" O.D. tubing
Unloader line	1/4" O.D. tubing
Coolant lines	1/2" O.D. tubing

IMPORTANT! PLEASE READ

When working on or around air brake systems and components, the following precautions should be observed:

1. Always block vehicle wheels. Stop engine when working under a vehicle. Depleting vehicle air system pressure may cause vehicle to roll. Keep hands away from chamber push rods and slack adjusters; they may apply as system pressure drops.
2. Never connect or disconnect a hose or line containing air pressure. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been depleted.
3. Never exceed recommended air pressure and always wear safety glasses when working with air pressure. Never look into air jets or direct them at anyone.
4. Never attempt to disassemble a component until you have read and understand recommended procedures. Some components contain powerful springs and injury can result if not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

COMPRESSOR TROUBLESHOOTING CHART

SYMPTOMS	CAUSE	REMEDY
1. Compressor passes excessive oil as evidenced by presence of oil at exhaust ports of valving or seeping from air strainer.	A. Restricted air intake.	A. Check engine or compressor air cleaner and replace if necessary. Check compressor air inlet line for kinks, excessive bends and be certain inlet lines have the minimum specified inside diameter. Recommended minimum inlet line inside diameter is 5/8". Recommended maximum air inlet restriction is 25" of water.
	B. Restricted oil return (to engine).	B. Oil return to the engine should not be in any way restricted. Check for excessive bends, kinks, and restrictions in the oil return line. Minimum recommended oil return line size is 5/8" O.D. tubing or equivalent I.D. (1/2" minimum). Return line must CONSTANTLY DESCEND from the compressor to the engine crankcase. Make certain oil drain passages in the compressor and mating engine surfaces are unobstructed and aligned. Special care must be taken when sealants are used with, or instead of, gaskets.
	C. Poorly filtered inlet air.	C. Check for damaged, defective or dirty air filter on engine or compressor. Check for leaking, damaged or defective compressor air intake components (i.e., induction line, fittings, gaskets, filter bodies, etc). The compressor intake should **not** be connected to any part of the exhaust gas recirculation (E.G.R.) system on the engine

SYMPTOMS	CAUSE	REMEDY
	D. Insufficient compressor cooling (compressor runs hot).	D. For air-cooled compressor or air-cooled portions of the compressor: 1. Remove accumulated grease, grime, or dirt from the cooling fins. Replace components found damaged. 2. Check for damaged cooling fins. Replace components found damaged. 3. Air-cooled compressors should not be used on engines equipped with fan clutches. For water-cooled compressor or water-cooled portions of the compressor: 1. Check for proper coolant line sizes. Minimum recommended size is 1/2" O.D. tubing. 2. Check the coolant flow through the compressor. Minimum allowable flow is 2.5 gallons per minute at engine governed speed. If low coolant flow is detected, inspect the coolant lines and fittings for accumulated rust scale, kinks and restrictions. 3. Water temperature should not exceed 200° F. 4. Optimum cooling is achieved when engine coolant flows into the compressor cylinder block at one end and out the compressor cylinder head at the opposite end.
	E. Contaminants not being regularly drained from system reservoirs.	E. Check reservoir drain valves to insure that they are functioning properly. It is recommended that the vehicle should be equipped with functioning automatic drain valves, or have all reservoirs drained to zero (0) psi daily, or optimally to be equipped with a desiccant-type air dryer prior to the reservoir system.
	F. Compressor runs loaded an excessive amount of time.	F. Vehicle system leakage should not exceed industry standards of 1 psi pressure drop per minute without brakes applied, and 3 psi pressure drop per minute with brakes applied. If leakage is excessive, check for system leaks and repair.
	G. Excessive engine crankcase pressure.	G. Test for excessive engine crankcase pressure and replace or repair crankcase ventilation components as necessary. (An indication of crankcase pressure is a loose or partially lifted dipstick.)
	H. Excessive engine oil pressure.	H. Check the engine oil pressure with a test gauge and compare the reading to the engine specifications. Bendix does not recommend restricting the compressor oil supply line because of the possibility of plugging the restriction with oil contaminants. Minimum oil supply line size is 1/4" O.D. tubing.

SYMPTOMS	CAUSE	REMEDY
	I. Faulty compressor.	I. Replace or repair the compressor only after making certain none of the preceding installation defects exist.
2. Noisy compressor operations.	A. Loose drive gear or pulley.	A. Inspect the fit of the drive gear on pulley o the compressor crankshaft. The pulley on gear must be completely seated and the crankshaft nut must be tight. If the compressor crankshaft surface or its keyway are damaged, it is an indication of loose drive components. If damage to the compressor crankshaft is detected, replace the compressor or the crankshaft. When installing the drive gear or pulley, torque the crankshaft nut to 100 foot pounds. DO NOT BACK OFF THE CRANKSHAFT NUT TO ALIGN THE COTTER PIN AND CASTELLATED NUT. (Some compressors do not use castellated nuts.) DO NOT USE IMPACT WRENCHES.
	B. Excessively worn drive couplings or gears.	B. Inspect drive gear and couplings and engine for excessive wear. Replace as necessary. (Non-metallic gears should be replaced when the compressor is changed.) 501 drive gear should be metal-type on Detroit Diesel engine.
	C. Compressor cylinder head or discharge line restrictions.	C. Inspect the compressor discharge port and discharge line for carbon build-up. If carbon is detected, check for proper cooling to the compressor. (See Cause and Remedy (D) under Symptom #1.) Inspect the discharge line for kinks and restrictions. Replace dischage line as necessary.
	D. Worn or burned out bearings.	D. Check for proper oil pressure in the compressor. **Minimum** required oil pressure; 5 psi engine idling, 15 psi maximum governed engine rpm. Check for excessive oil temperature—should not exceed 240° F.
	E. Faulty compressor.	E. Replace or repair the compressor after determining none of the preceding installation defects exist.
3. Excessive build-up and recovery time. Compressor should be capable of building air system from 85-100 psi in 40 seconds with engine at full governed rpm. Minimum compressor performance is certified to meet Federal requirements by the vehicle manufacturer. Do not downsize the original equipment compressor.	A. Dirty induction air filter.	A. Inspect engine or compressor air filter and replace if necessary.
	B. Restricted induction line.	B. Inspect the compressor air induction line for for kinks and restrictions and replace as necessary.
	C. Restricted discharge line or compressor discharge cavity.	C. Inspect the compressor discharge port and line for restrictions and carbon build-up. If a carbon build-up is found, check for proper compressor cooling. Replace faulty sections of the discharge line.

SYMPTOMS	CAUSE	REMEDY
	D. Slipping drive components.	D. Check for faulty drive gears and couplings and replace as necessary. Check the condition of drive belts and replace or tighten, whichever is appropriate.
	E. Excessive air system leakage.	E. Test for excessive system leakage and repair as necessary. Use the following as a guide: Build system pressure to governor cutout and allow the pressure to stabilize for one minute. Using the dash guage, note the system pressure and the pressure drop after two minutes. The pressure drop for Pre-1975 vehicles should not exceed: 1. 4 psi for a single vehicle. 2. 6 psi for a tractor trailer. 3. 10 psi for a tractor and 2 trailers. The pressure drop for Post-1975 vehicles should not exceed: 1. 2 psi in **each** reservoir for a single vehicle. 2. 6 psi in **each** reservoir for a tractor and trailer. 3. 8 psi in **each** reservoir for a tractor and 2 trailers.
	F. Sticking unloader pistons and plungers.	F. Check the operation of the unloading pistons in the inlet cavity of the compressor. Both pistons should have the plunger flanges resting on the inlet cavity floor when the compressor is loaded (pumping air). If the pistons and plunger are not fully retracted, check for proper operation of the compressor air governor. If the governor is operating properly, replace the unloader pistons and plungers and inspect their bores in the cylinder block. Clean lubricate as necessary. Inspect for bent, kinked or blocked tubing leading to or from the governor.
	G. Faulty compressor.	G. Replace or repair the compressor after determining none of the preceding installation defects exist.
4. Compressor fails to unload.	A. Faulty governor or governor installation.	A. Test the governor for proper operation and inspect air lines to and from the governor for kinks or restrictions. Replace or repair the governor or its connecting air lines.
	B. Faulty or worn unloader pistons or bores.	B. Inspect for worn, dirty or corroded unloader pistons and their cylinder block bores. Replace as necessary.
5. Compressor leaks oil.	A. Damaged mounting gasket.	A. Check the compressor mounting bolt torque. If the mounting bolt torque is low, replace the compressor mounting gasket before retorquing the mounting bolts.

SYMPTOMS	CAUSE	REMEDY
	B. Cracked crankcase, cylinder block or end cover.	B. Visually inspect the compressor exterior for cracked or broken components. Cracked or broken crankcases or mounting flanges can be caused by loose mounting bolts. The end cover can be cracked by over-torquing fitting or plugs installed in the end cover. Replace or repair the compressor as necessary.
	C. Loose end cover or cylinder block cap screws.	C. Check the cap screw torques and tighten as necessary.
	D. Loose oil supply or return line fittings.	D. Check the torque of external oil line fittings and tighten as necessary.
	E. Porous compressor casting.	E. Replace the compressor if porosity is found.
	F. Mounting flange or end cover, O-Ring or gasket—missing, cut, or damaged.	F. Replace as necessary.
6. Compressor constantly cycles (compressor remains unloaded for a very short time.)	A. Leaking compressor unloader pistons.	A. Remove the compressor inlet air strainer or fitting. With the compressor unloaded (not compressing air), check for air leakage around the unloader pistons. Replace as necessary.
	B. Faulty governor.	B. Test the governor for proper operation and repair or replace as necessary.
	C. Excessive system leakage.	C. Test for excessive system leakage as instructed in Symptom 3, Remedy E. Reduce leakage wherever possible.
	D. Excessive reservoir contaminants.	D. Drain reservoirs.
7. Compressor leaks coolant.	A. Improperly installed plugs and coolant line fittings.	A. Check torque of fittings and plugs and tighten as necessary. Over-torque fittings and plugs can crack the head or block casting.
	B. Freeze cracks due to improper anti-freeze strength.	B. Test anti-freeze and strengthen as necessary. Check coolant flow through compressor to assure the proper anti-freeze mixture reaches the compressor.
	C. Faulty compressor (porous castings).	C. If casting porosity is detected, replace the compressor.
8. Compressor head gasket failure.	A. Restricted discharge line.	A. Clear restriction or replace line.
	B. Loose head bolts.	B. Tighten evenly to a torque of 25-30 foot pounds.
	C. Faulty compressor or head gasket.	C. Check for rough or poorly machined head or block surfaces. Replace necessary components.

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General Information

The 4.5″ bore, V8 (Direct Injection) Engine can be reconditioned to provide performance characteristics comparable to a new engine. The reconditioned engine will operate satisfactorily if certain reconditioning precautions are observed.

Performance and oil control comparable to a new engine can be obtained only if the necessary machining is done to the required Specifications. Cylinder block reconditioning requires an automatic honing machine to control size, surface finish and cross hatch pattern of the cylinder bores. A manually operated hone does not give satisfactory results and is not recommended.

To facilitate reconditioning, pistons and rings are available 0.51 mm (.020 in) and 1.02 mm (.040 in) oversize.

Connecting rods and main bearings are available 0.25 mm (.010 in), 0.51 mm (.020 in) and 1.27 mm (.050 in) undersize.

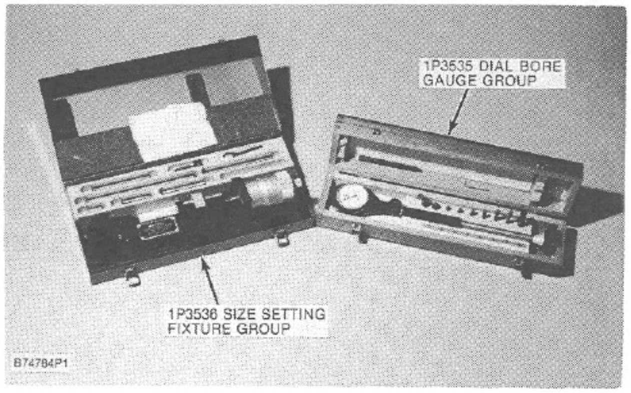
Main bearings are available with a 0.25 mm (.010 in) oversize outside diameter. These bearings are for cylinder blocks that have had the bore for the main bearings bored oversize.

Basic Block

Cylinder Block Honing

The following preliminary check is essential to determine if honing is necessary, and if so, the size to hone.

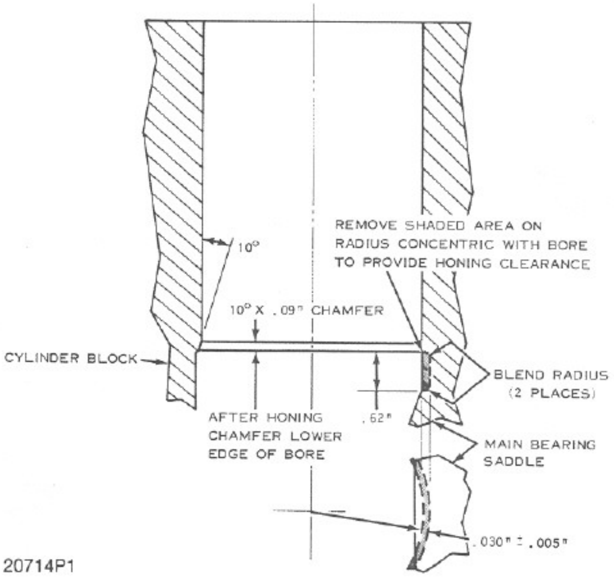
Measure all cylinder bores during disassembly using the 1P3537 Bore Gauging Group. This Group includes a 1P3535 Dial Bore Gauge Group and a 1P3536 Size Setting Fixture Group. The bore gauging group provides more accurate measurement than other methods, such as inside micrometers. When setting the gauge, always be sure the gauge pin has sufficient travel to measure the points of maximum wear in the bore. In a cylinder bore, maximum wear is usually across the diameter perpendicular to the crankshaft centerline, either at the top or bottom of ring travel. Normal wear usually will not exceed 0.51 mm (.020 in); however, if bore wear is greater than 0.51 mm (.020 in), hone the block 1.02 mm (.040 in) oversize. The fact that the block can be honed both 0.51 mm (.020 in) and 1.02 mm (.040 in) oversize will allow a block to be reconditioned twice under normal wear conditions. The standard bore size is 114.300 to 114.338 mm (4.5000 to 4.5015 in).


1P3535 DIAL BORE GAUGE GROUP
1P3536 SIZE SETTING FIXTURE GROUP
B74784P1

1P3537 Bore Gauging Group

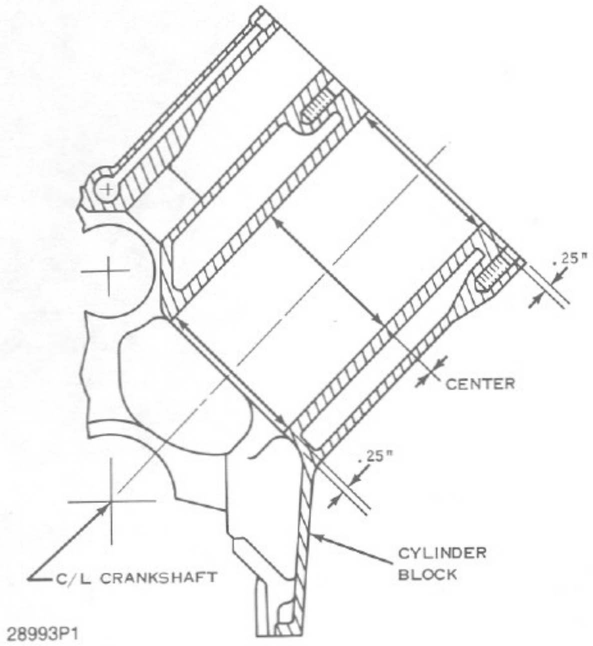
When reconditioning an engine, the bore size is the determining factor as to the necessity of honing the bores. If bores are worn 0.15 mm (.006 in) more than the standard size, the block should be honed. However, additional service may be obtained without honing if wear does not exceed the maximum wear limit of 0.216 mm (.0085 in).

Before honing, inspect the bottom of each cylinder bore adjacent to the main bearing saddle or web. Some of the saddles may overlap the edge of cylinder bores enough to interfere with honing. Where overlap exists, machine a relief in the saddle to provide clearance for the honing tool. The radius of the relief must be concentric with the cylinder bore and 0.76 ± 0.13 mm (.030 ± .005 in) larger than the bore radius. The relief extends 15.7 mm (.62 in) beyond the bottom of the bore, as shown. This provides adequate clearance for honing.


10°
REMOVE SHADED AREA ON RADIUS CONCENTRIC WITH BORE TO PROVIDE HONING CLEARANCE
10° X .09" CHAMFER
CYLINDER BLOCK
BLEND RADIUS (2 PLACES)
AFTER HONING CHAMFER LOWER EDGE OF BORE
.62"
MAIN BEARING SADDLE
.030" ± .005"
20714P1

Relief In Saddles And Chamfer After Honing

When honing, check bore size at several locations in the length of the bore and around the circumference. Specifically measure at points perpendicular to the crankshaft centerline at locations 6.4 mm (.25 in) from each end and at center of bore. These three specific locations are primary gauge points during and after honing.



Primary Gauging Points

When honing cylinder blocks, maintain the specific dimensional surface finish and cross hatch tolerances to obtain satisfactory oil control. The tolerances specified are virtually the same as those used for original bore finish at the factory, and can be obtained with an automatic honing machine such as the Sunnen CK-10. This machine has been evaluated and found to give satisfactory results.

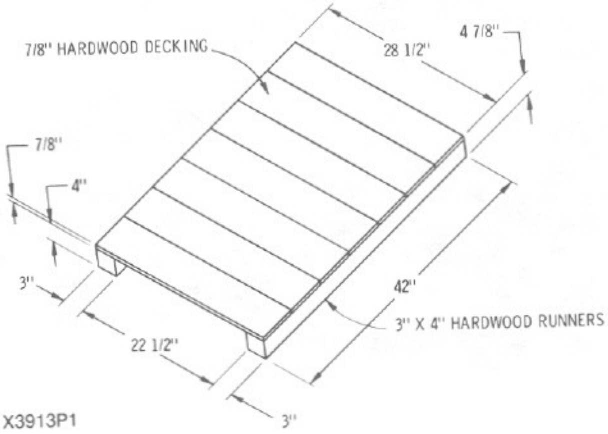
The Sunnen CK-10 machine is available from Sunnen Products Company, 7910 Manchester Avenue, St. Louis, Missouri, 63143.

Due to the cost of suitable honing equipment, it may be more expedient to have the honing done by a shop equipped with a Sunnen CK-10 or equivalent.

Transit Preparation

The following Steps can prevent damage to the block in transit to a shop.

1. Completely disassemble, but do not clean block. The residual oil on the surface will prevent rust.
2. Enclose the block in an industrial plastic bag and position it with the oil pan surface on a suitable wood pallet or equivalent. Dimensions of a suitable wood pallet are shown.



Transporting Pallet

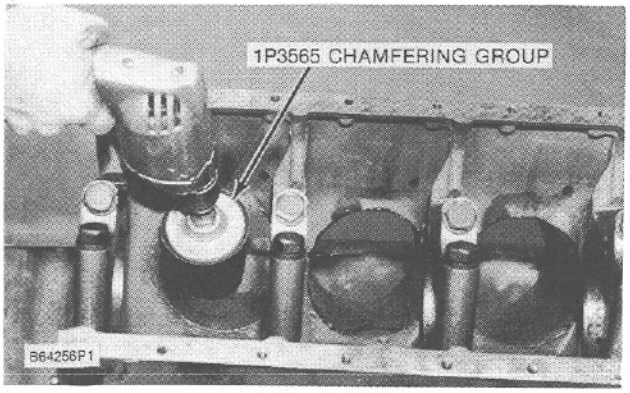
3. Cover the block with 12.7 mm (½ in) thick plywood or equivalent, and band block to the pallet.
4. Follow similar instructions when block is returned. To prevent rust, the block should not be cleaned after honing; the film of honing oil provides ample protection from rusting.

NOTE: If blocks are stored for any length of time, clean and anti-rust after honing.

Cleaning Procedure

After honing is completed, and before assembling the engine, the cylinder block must be cleaned and prepared according to the following instructions.

1. If not previously removed, the camshaft bearings must be removed to permit thorough cleaning of the oil passages. To remove the bearings, see the topic Camshaft Bearings Removal And Installation.
2. Use 1P3565 Chamfering Group, remove the sharp corner at the bottom of the cylinder bores as shown. This is essential to prevent scuffing the piston skirts. This chamfer should be approximately 10° × 2.3 mm (10° × .09 in).



Chamfering Bore

NOTICE
Avoid damage to the cylinder bore surface or any other parts.

3. Use the 1P5580 Brush Group and a strong detergent and water solution to clean the following areas of the block.

A. Main oil gallery and supply passage. Use the 1P5572 or 1P5573 Brush and stroke several times while rotating the brush.

B. Camshaft bearing oil passages. Use the 1P5571 Brush and stroke several times while rotating the brush.

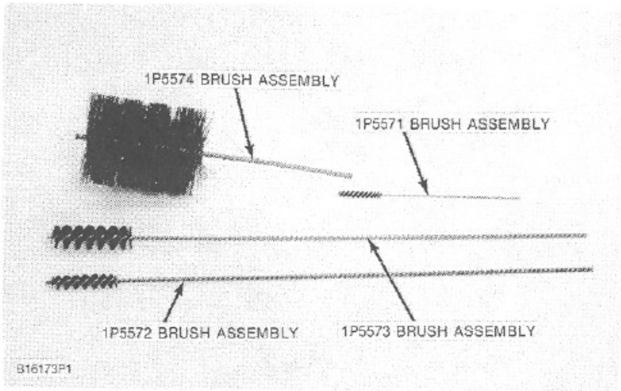
C. Cylinder bores. Use the 1P5574 Brush and stroke each bore for one minute while rotating the brush at 1000 rpm.

NOTICE
Incomplete cleaning will result in piston seizure or rapid wear of cylinder bores, pistons and rings. Only thorough rotary brushing with a strong detergent and water solution satisfactorily removes abrasive particles.

4. To clean the piston cooling jets, use a #50 drill or a length of 1.78 mm (.070 in) wire and push through the jet. Be sure the groove in the main bearing bores and the counterbores for piston cooling jets are clean and free of debris.

5. Thoroughly clean the cylinder block in an agitator-type cleaning tank. This type of cleaning should follow the brushing of the cylinder bores but is not sufficient by itself for cleaning.

6. Coat all machined surfaces immediately after cleaning with engine oil (SAE 30). Keep the block covered to exclude dirt until assembled.



1P5580 Brush Group

Remove and Install Piston Cooling Jets

Use a 3/16 in diameter punch approximately 305 mm (12 in) long to remove the piston cooling jets. Put the punch in the engine cylinder bore and drive the piston cooling jet into the main bearing bore.

Use a FT1542 Driver to install the piston cooling jets in the main bearing bores. After installation check the orifice size in the piston cooling jet. A #50 drill or a length of 1.78 mm (.070 in) diameter wire must pass through the jet.

SUNNEN CK-10 MACHINING DATA

Item	Rough	Semifinish	Finish
0.51 mm (.020 in) oversize bore	114.694 ± 0.03 mm (4.5155 ± .001 in)	114.770 ± 0.013 mm (4.5185 ± .0005 in)	114.821 ± 0.013 mm (4.5405 ± .0005 in)
1.02 mm (.040 in) oversize bore	115.202 ± 0.03 mm (4.5355 ± .001 in)	115.278 ± 0.013 mm (4.5385 ± .0005 in)	115.329 ± 0.013 mm (4.5405 ± .0005 in)
Cylinder length	203.2 mm (8 in)	203.2 mm (8 in)	203.2 mm (8 in)
Hone head	CK-3000	CK-3000	CK-3000
Stroke scale	69.9 mm (2.75 in)	69.9 mm (2.75 in)	69.9 mm (2.75 in)
Stroke length setting	203.2 mm (8 in)	203.2 mm (8 in)	203.2 mm (8 in)
Rotation speed (rpm)	125	125	125
Strokes per minutes	49	49	37
Feed ratchet	14	14	14
Top over stroke	9.53 mm (.375 in)	9.53 mm (.375 in)	9.53 mm (.375 in)
Stone	EHU-123	EHU-525	JHU-625
Load meter	85	75	40
Stock removal rate per minute	0.13 mm (.005 in)	0.064 mm (.0025 in)	0.051 to 0.064 mm (.0020 to .0025 in)
Honing-per each 0.03 mm (.001 in) stock removal, advance feed	0.03 mm (.001 in)	0.08 mm (.003 in)	0.08 mm (.003 in)
Surface finish (micro-inches)	–	–	12-20

NOTE: Mount cylinder block on .675″ riser plates. Use 42″ long bar, move clamps and riser blocks to extreme ends of carriage.

SPECIFICATIONS AND TOLERANCES

Dimension Location	Standard Size	0.51 mm (.020") Oversize	1.02 mm (.040") Oversize
Cylinder bore-finished	114.300 to 114.338 mm (4.5000 to 4.5015 in)	114.821 ± 0.013 mm (4.5205 ± .0005 in)	115.329 ± 0.013 mm (4.5405 ± .0005 in)
**Allowable wear limit	114.45 mm (4.506 in)	114.96 mm (4.526 in)	– –
Maximum wear limit	114.53 mm (4.509 in)	115.03 mm (4.529 in)	115.54 mm (4.529 in)
Surface finish (micro-inches)	12 to 20	12 to 20	12 to 20
Crosshatch included angle	140 to 150	138 to 150	138 to 150
Rough hone	–	114.694 ± 0.03 mm (4.5155 ± .001 in)	115.202 ± 0.03 mm (4.5355 ± .001 in)
Semifinish hone	–	114.770 ± 0.013 mm (4.5185 ± .0005 in)	115.278 ± 0.013 mm (4.5385 ± .0005 in)
***Top ring gap new	0.572 ± 0.190 mm (.0225 ± .0075 in)	0.572 ± 0.190 mm (.0225 ± .0075 in)	0.572 ± 0.190 mm (.0225 ± .0075 in)
**Allowable wear limit	1.14 mm (.045 in)	1.14 mm (.045 in)	1.14 mm (.045 in)
Maximum wear limit	1.40 mm (.055 in)	1.40 mm (.055 in)	1.40 mm (.055 in)
***Oil ring gap-new	0.508 ± 0.254 mm (.0200 ± .0100 in)	0.508 ± 0.254 mm (.0200 ± .0100 in)	0.508 ± 0.254 mm (.0200 ± .0100 in)
**Allowable wear limit	0.97 mm (.038 in)	0.97 mm (.038 in)	0.97 mm (.038 in)
Maximum wear limit	1.14 mm (.045 in)	1.14 mm (.045 in)	1.14 mm (.045 in)
Top ring vertical clearance in groove-new	0.076 to 0.140 mm (.0030 to .0055 in)	0.076 to 0.140 mm (.0030 to .0055 in)	0.076 to 0.140 mm (.0030 to .0055 in)
**Allowable wear limit	0.28 mm (.011 in)	0.28 mm (.011 in)	0.28 mm (.011 in)
Maximum wear limit	0.36 mm (.014 in)	0.36 mm (.014 in)	0.36 mm (.014 in)
Oil ring vertical clearance in groove-new	0.025 to 0.076 mm (.0010 to .0030 in)	0.025 to 0.076 mm (.0010 to .0030 in)	0.025 to 0.076 mm (.0010 to .0030 in)
**Allowable wear limit	0.15 mm (.006 in)	0.15 mm (.006 in)	0.15 mm (.006 in)
Maximum wear limit	0.20 mm (.008 in)	0.20 mm (.008 in)	0.20 mm (.008 in)

* Tolerance includes out-of-round, taper and any other irregularities. Take final measurements with blocks stabilized to room temperature. Finished bore must clean up to 100%.

** Allowable wear limit is the suggested wear limit for a general overhaul. However, additional service may be obtained without honing the block if wear does not exceed maximum wear limits. (Cylinder bore wear is measured at the top and bottom of ring travel.)

*** To be measured in unworn area of bore.

NOTE: When the size of the cylinder bores exceeds the maximum wear limit of 115.545 mm (4.5490 in) replacement of the cylinder block or installation of cylinder sleeves is necessary.

TIGHTENING PROCEDURE FOR THE BOLTS FOR MAIN BEARING CAPS
Tightening Procedure
1. Put 2P2506 Thread Lubricant on bolt threads and washer face. 2. Tighten to 40 ± 4 N•m (30 ± 3 lb ft). 3. Put a mark on each bolt and cap. 4. Tighten bolts from mark an added 120° ± 5°.

Main Bearing Bores

With the main bearing caps installed and tightened to the torque given in the chart Tightening Procedure For The Bolts For Main Bearing Caps, check main bearing bore size using the 1P3537 Gauging Group. If the main bearing bore is not within 94.171 ± 0.038 mm (3.7075 ± .0015 in), replace the main bearing cap. It is necessary to line bore the replacement caps. See the topic Line Boring Main Bearing Cap.

When installing main bearings caps on a reconditioned engine use new bearing cap bolts and washers.

Main Bearing Cap Guide Width

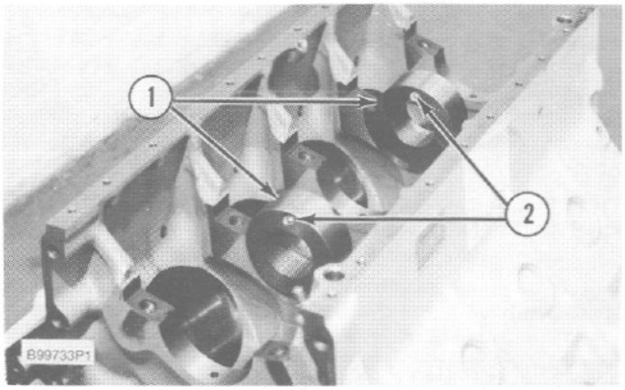
Check the width of the main bearing cap guide. The guide width of a new cap is 166.624 ± 0.018 mm (6.5600 ± .0007 in). Replace main bearing caps that are less than the minimum width of 166.573 mm (6.5580 in). It is necessary to line bore the replacement service caps. See the topic Line Boring Main Bearing Cap.

When installing main bearing caps on a reconditioned engine, use new main bearing cap bolts and washers.

Line Boring Main Bearing Caps

When reconditioning a block, and one main bearing cap is replaced, line bore the replaced cap. If it is necessary to replace more than one cap, it is recommended that all of the main bearing bores be line bored. See the topic Line Boring Main Bearing Bores.

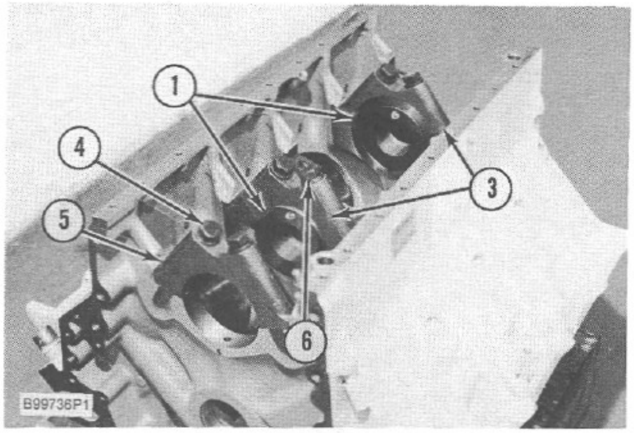
Clean bearing caps and saddles. Remove all nicks from pan rail. Plug oil holes in block with grease to prevent chips from entering oil passages.



Centering Rings In Block
(1) Centering Rings. (2) Oiler.

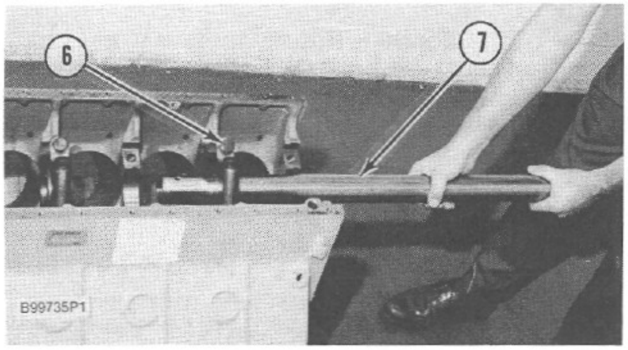
Place 1P2344 Centering Rings (1), with oiler (2) up, on each side of the cap being replaced. For an end cap, place 1P2344 Centering Rings (1) in the second and fourth main bearing bores.

Mark new cap to correspond with number of saddle and install the new unbored cap (5). Mark cap and saddle "OS" for oversize next to location number. Tighten the unbored cap bolts (4) to the torque shown in the chart Tightening Procedure For The Bolts For Main Bearing Caps. Place the original bearing caps (3) over the centering rings (1). Tighten the original bearing cap bolts (6) hand tight.



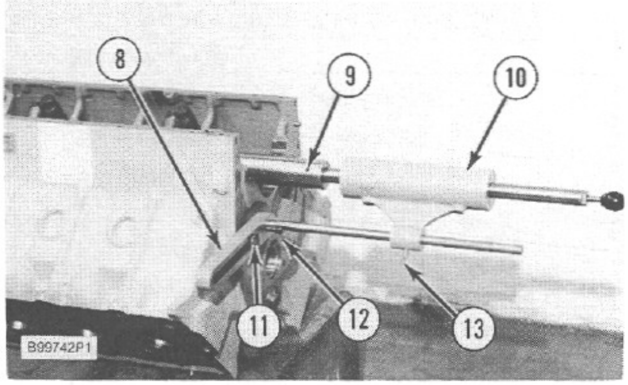
Centering Rings Installed
(1) 1P2344 Centering Rings. (3) Original bearing caps. (4) Bolts (two). (5) Unbored cap. (6) Bolts (four).

Oil boring bar (7) and insert it through centering rings (1). Tighten bolts (6) to a minimum of 25 N•m (20 lb ft) and a maximum of 70 N•m (50 lb ft) while spinning boring bar (7) to check for binding. Centering rings (1) must be seated in bearing saddles after tightening.



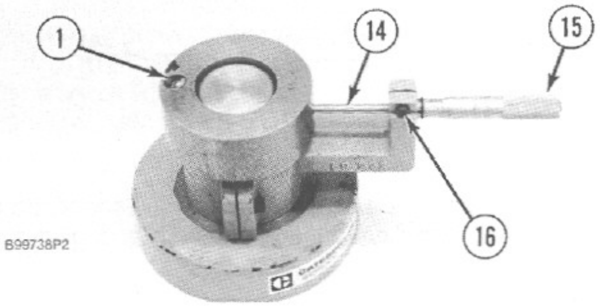
Installing Boring Bar
(6) Bolts (four). (7) 1P2352 Boring Bar.

Bolt torsion bar assembly (8) loosely to opposite end of block from which boring bar will be driven. Install feed assembly (10) into boring bar and tighten setscrew (9). Slide feed assembly (10) onto torsion bar assembly (8) and tighten bolt (11). Tighten bolt (12) finger tight. Boring bar must slide in and out freely after these tightening operations. Tighten thumbscrew (13).



Feed Assembly Installed
(8) 1P2369 Torsion Bar Assembly. (9) Setscrew. (10) 5P2981 Feed Assembly. (11) Bolt. (12) Bolt. (13) Thumbscrew.

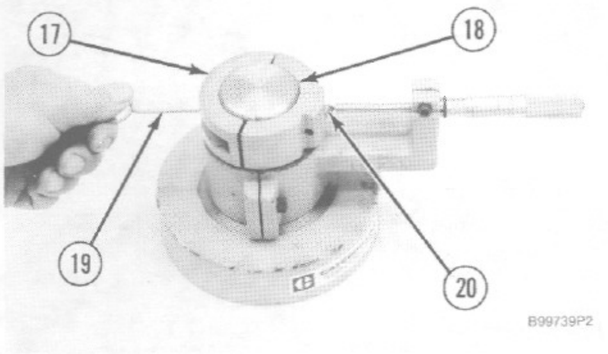
To set tool in tool holder. Set micrometer (15) to 94.171 mm (3.7075 in). Place centering ring (1) on 1P2370 Micrometer Bracket Assembly. Move micrometer (15) until spindle (14) contacts centering ring (1). Tighten bolt (16). Back off micrometer thimble and recheck micrometer setting. Repeat above steps until micrometer setting is accurate.



Setting Micrometer
(1) 1P2344 Center Ring. (14) Micrometer spindle. (15) Micrometer. (16) Bolt.

Place tool holder (17) on the 1P2370 Micrometer Bracket Assembly. Align mark on tool holder (17) with hole in shaft (18). Place tool bit (20) in tool holder (17) and set the micrometer 1.78 mm (.070 in) less than the finish bore diameter of 94.425 ± 0.013 mm (3.7175 ± .0005 in). Turn the bracket assembly arm until micrometer spindle aligns with tool bit (20). Adjust tool bit (20) by pushing it with the 9S8521 Rod (19) until tip of tool bit (20) touches micrometer spindle.

NOTICE
Do not sweep micrometer spindle across tool bit.

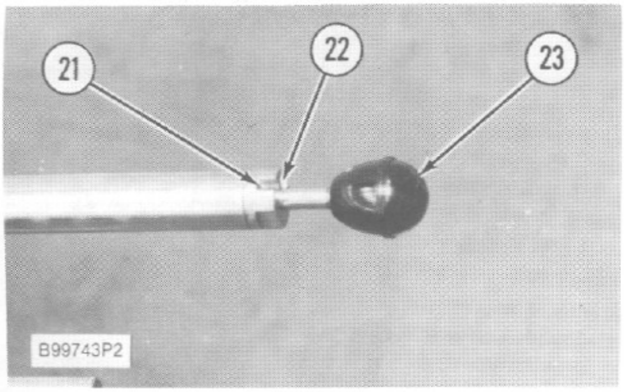


Setting Tool Bit
(17) 1P2366 Tool Holder Assembly. (18) Shaft. (19) 9S8521 Rod. (20) Tool bit.

Use a maximum of 0.64 mm (.025 in) rough cuts and 0.25 mm (.010 in) finish cuts.

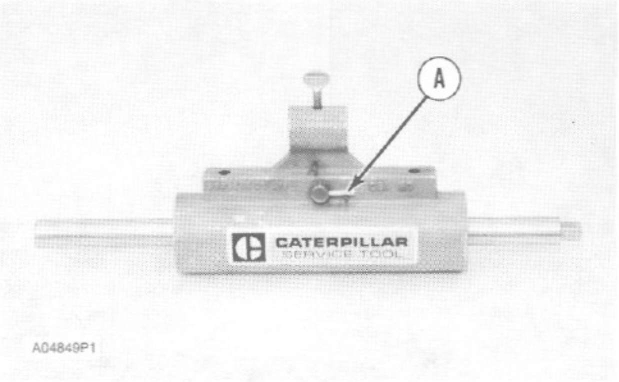
Wipe boring bar and tool holder clean. Place tool holder on the boring bar, with tool bit cutting edge facing the direction of rotation. Assemble the tool holder by placing lower half over the bolts, slide into slot and tighten bolts. Slide boring bar in until tool is approximately 3.0 mm (.12 in) from the bore. Compare tool cutting tip with bore surface while turning bore bar by hand, to insure correct tool setting.

Set feed mechanism into feed by turning knob (23) until pin (22) drops into slot (21).



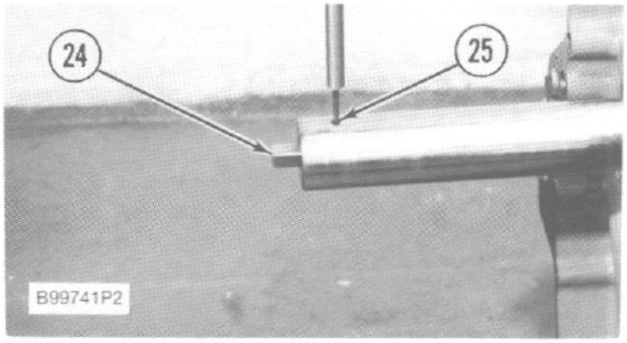
Feed Engaged
(21) Slot. (22) Pin. (23) Knob.

NOTE: To set the feed mechanism into feed on later units, turn lever (A) up (the direction of arrow).



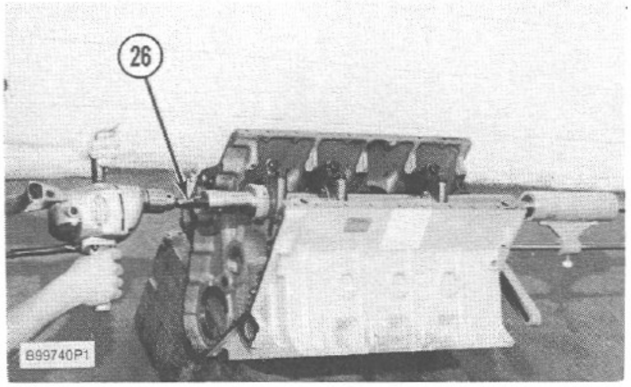
Later Feed Mechanism
(A) Lever.

Place adapter (24) into boring bar and tighten setscrew (25).



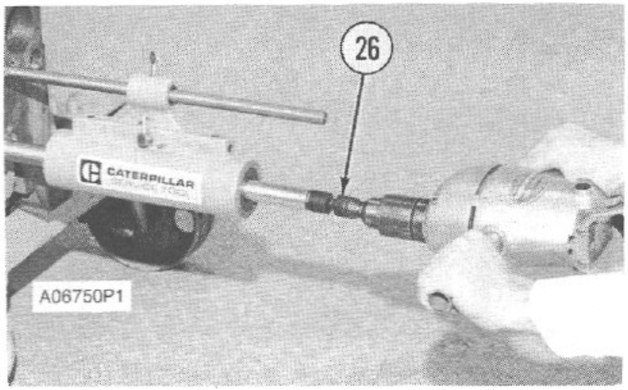
Adapter Installed
(24) 1P2364 Adpater. (25) Setscrew.

Apply layout bluing to the bearing cap and bearing bore. Oil the centering rings. Do not use lubricant on the cutter. Use a one-half inch electric drill with universal joint (26) to feed tool through the bore. Service main bearings with 0.25 mm (.010 in) oversize outside diameter are available to permit the bore to be bored oversize. Bore the bore to 94.425 ± 0.013 mm (3.7175 ± .0005 in).



Boring Bearing Bore
(26) 1P2363 Universal.

NOTE: If you use the later feed mechanism, the tool can be driven from either the boring bar or the feed mechanism.

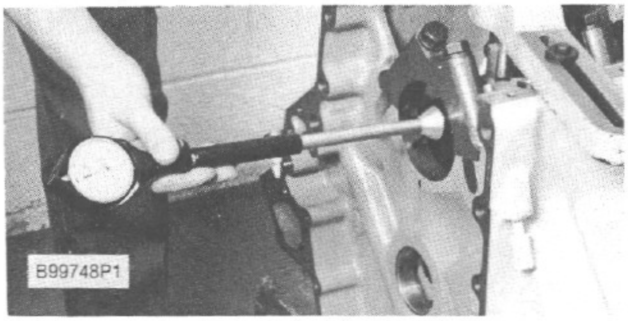


Driving Through Feed Mechanism
(Typical Example)
(26) 1P2363 Universal

The bluing applied to the bearing bore indicates the condition of the bore at the correct bore size. If bluing shows an out of round condition, check the largest diameter (indicated by remaining bluing) in relation to the smallest diameter (indicated by lack of bluing). The difference of the two must not exceed 0.025 mm (.0010 in).

If bluing indicates a step in the joint face, measure the diameter at the step in relation to the smallest diameter. A step of 0.013 mm (.0005 in) on one or both sides is permissible. A maximum of 0.025 mm (.0010 in) over the nominal finish bore diameter is permissible if within the described limits.

To check the bore diameter, set the 1P3535 Dial Bore Gauge to 94.425 mm (3.7175 in).



Checking Bore
(Typical Example)

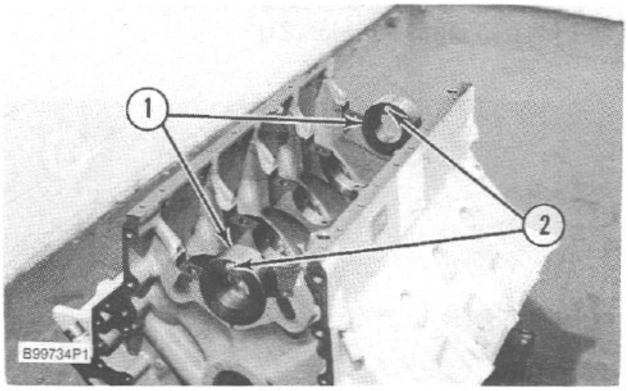
Line Boring Bearing Bores

Line bore all main bearing bores if bearing caps or saddles are distorted.

Clean bearing caps and saddles. Remove all nicks from pan rail. Plug oil holes in block with grease to prevent chips from entering oil passages.

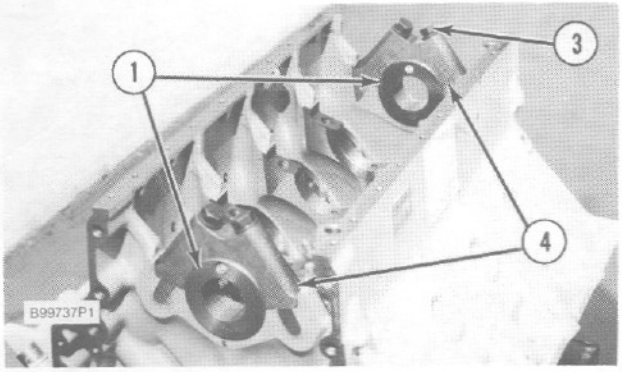
Place 1P2344 Centering Rings (1), with oiler (2) up, at each end of block. If an end bore is distorted, use the next good bore.

NOTE: There must be two good bores for locating centering rings.

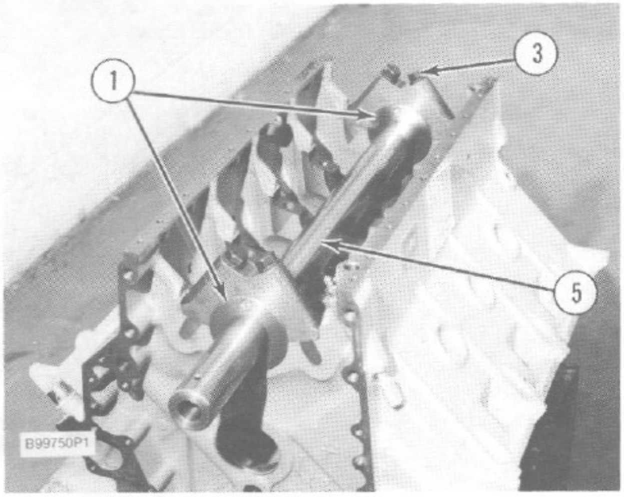


Centering Rings In Block
(1) 1P2344 Center Rings. (2) Oiler.

Place original bearing caps (4) over the centering rings (1). Tighten bolts (3) hand tight.



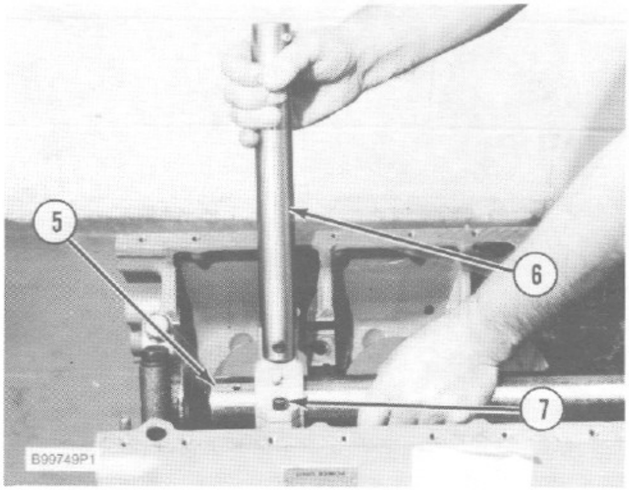
Centering Rings Installed
(1) 1P2344 Centering Rings. (3) Bolts (four). (4) Bearing caps.



Boring Bar Installed
(1) 1P2344 Centering Rings. (3) Bolts (four). (5) 1P2352 Boring Bar.

Oil boring bar (5) and insert it through centering rings (1). Tighten bolts (3) to a minimum of 25 N•m (20 lb ft) and a maximum of 70 N•m (50 lb ft) while spinning boring bar (5) to check for binding. Centering rings (1) must be seated in bearing saddles after tightening.

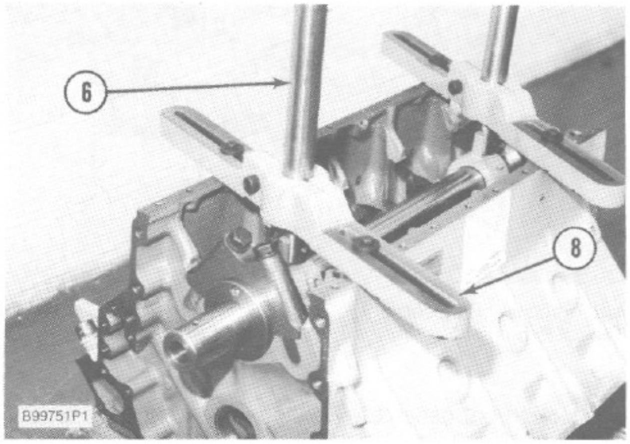
Slide boring bar (5) out of one end of block and install bearing assemblies (6) on boring bar (5). Slide boring bar (5) back through centering ring. Adjust bearing by tightening bolt (7) until bar begins to bind, then back off until boring bar (5) spins easily.



Installing Bearing Assemblies
(5) 1P2352 Boring Bar. (6) 1P2373 Bearing assembly (two). (7) Bolt.

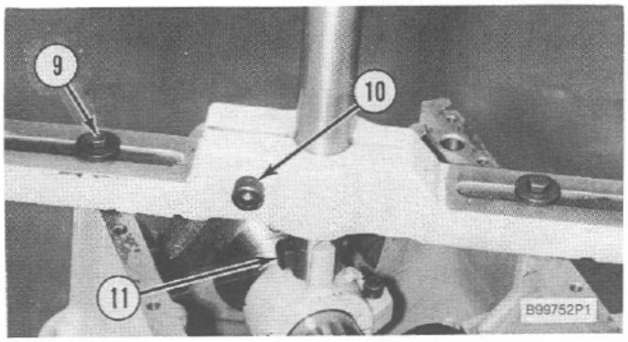
Install bridge assemblies (8) over bearing assemblies (6). Position bridge assemblies (8) on block as shown with thicker portion up.

NOTE: Bridge assemblies must be on block as shown for tool holder clearance at each bore.



Bridge Assemblies Installed
(6) 1P2373 Bearing Assembly (two). (8) 1P2343 Bridge Assembly (two).

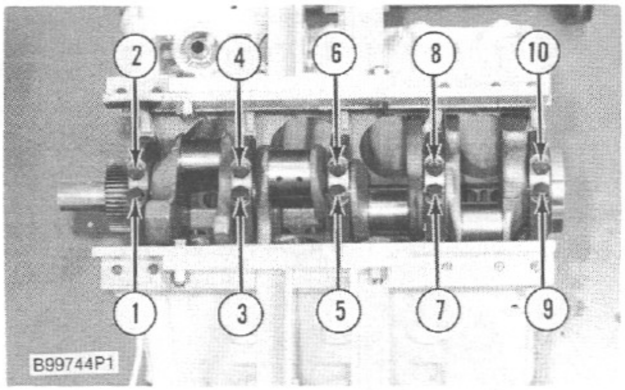
Tighten bolts (9) finger tight. Tighten bolt (10) lightly. Tighten bolt (11). Loosen, then tighten bolts (9) and bolt (10). Spin boring bar (5) during all tightening operations. Repeat above procedure if boring bar (5) binds.



Bolt Location
(9) Bolt (two). (10) Bolt. (11) Bolt.

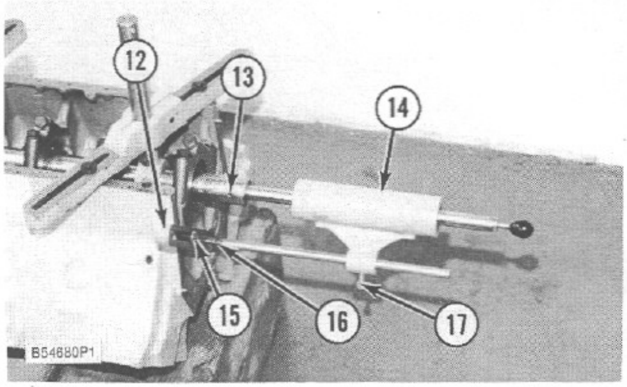
Remove original bearing caps and centering rings. Mark new caps to correspond with numbers on saddle and install new service caps. Mark caps and saddles "OS" for oversize next to location number.

Be sure to install new bolts. Put engine oil on bolt threads and washer face. Tighten bolts in number sequence to 40 ± 4 N•m (30 ± 3 lb ft), put a mark on each bolt and cap. Tighten all bolts by number from mark an additional 120 ± 5°.



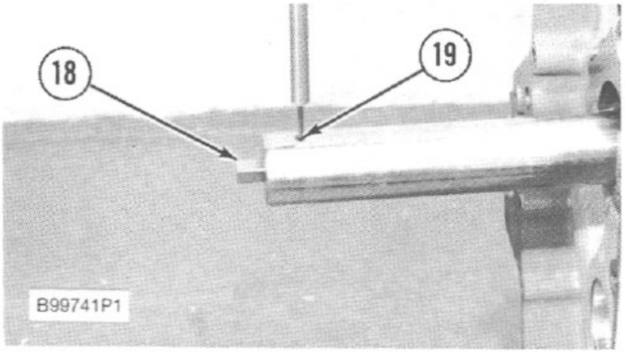
Bolt Tightening Sequence
(Typical Example)

Bolt torsion bar assembly (12) loosely to opposite end of block from which boring bar will be driven. Install feed assembly (14) into boring bar and tighten setscrew (13). Slide feed assembly (14) onto torsion bar assembly (12) and tighten bolt (15). Tighten bolt (16) finger tight. Boring bar must slide in and out freely after these tightening operations. Tighten thumbscrew (17).



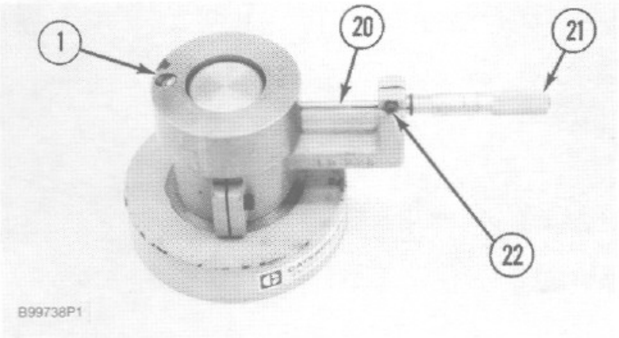
Feed Assembly Installed
(12) 1P2369 Torsion Bar Assembly. (13) Setscrew. (14) 5P2981 Feed Assembly. (15) Bolt. (16) Bolt. (17) Thumbscrew.

Place adapter (18) into boring bar and tighten setscrew (19).



Adapter Installed
(18) 1P2364 Adapter. (19) Setscrew.

Put tool in tool holder, set micrometer (21) to 94.171 mm (3.7075 in). Place centering ring (1) on the 1P2370 Micrometer Bracket Assembly. Move micrometer (21) until spindle (20) contacts centering ring (1). Tighten bolt (22). Back off micrometer thimble and check micrometer setting. Repeat above steps until micrometer setting is accurate.

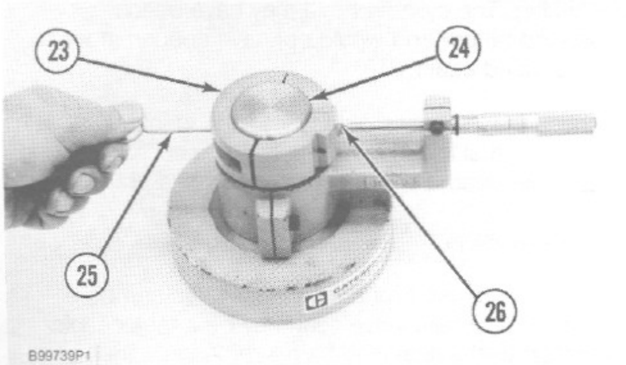


Setting Micrometer
(1) 1P2344 Centering Ring. (20) Micrometer spindle.
(21) Micrometer. (22) Bolt.

Place tool holder (23) on the 1P2370 Micrometer Bracket Assembly. Align mark on tool holder (23) with hole in shaft (24). Place tool bit (26) in tool holder (23) and set the micrometer 1.78 mm (.070 in) less than the finish bore diameter of 94.425 ± 0.013 mm (3.7175 ± .0005 in). Turn the bracket adjustment arm until micrometer spindle aligns with tool bit (26). Adjust tool bit (26) by pushing it with the 9S8521 Rod (25) until tip of bit (26) touches micrometer spindle.

NOTICE

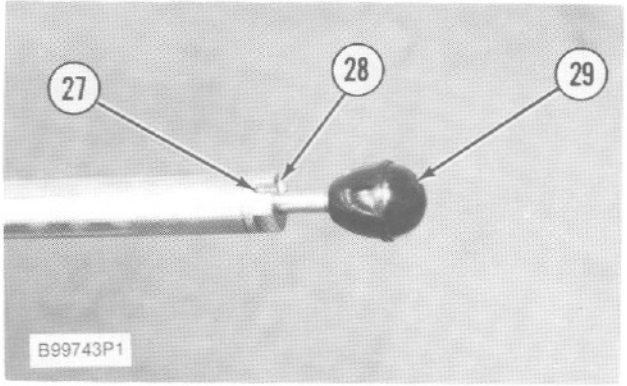
Do not sweep micrometer spindle across tool bit.



Setting Tool Bit
(23) 1P2366 Tool Holder Assembly. (24) Shaft. (25) 9S8521 Rod.
(26) Tool bit.

Use a maximum of 0.64 mm (.025 in) for rough cuts and 0.25 mm (.010 in) for finish cuts.

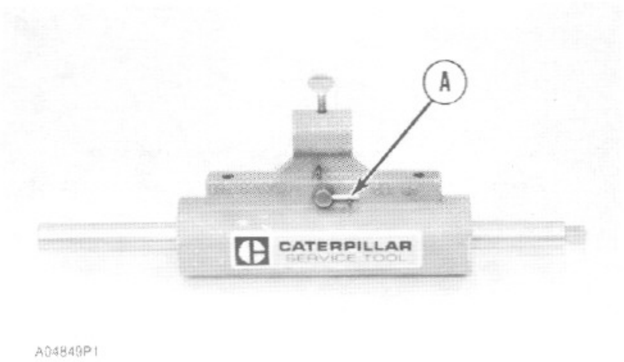
Wipe the boring bar and tool holder clean. Place tool holder on the boring bar, with tool bit cutting edge facing the direction of rotation. Assemble the tool holder by placing lower half over the bolts, slide into slot and tighten bolts. Slide boring bar in until tool is approximately 3.0 mm (.12 in) from the bore. Compare tool cutting tip with bore surface while turning boring bar by hand, to insure correct tool setting.



Feed Engaged
(27) Slot. (28) Pin. (29) Knob.

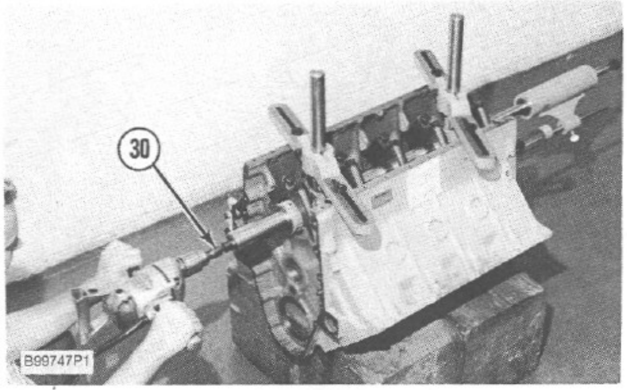
Set feed mechanism into feed by turning knob (29) until pin (28) drops into slot (27).

NOTE: To set the feed mechanism into feed on later units, turn lever (A) up (the direction of arrow).

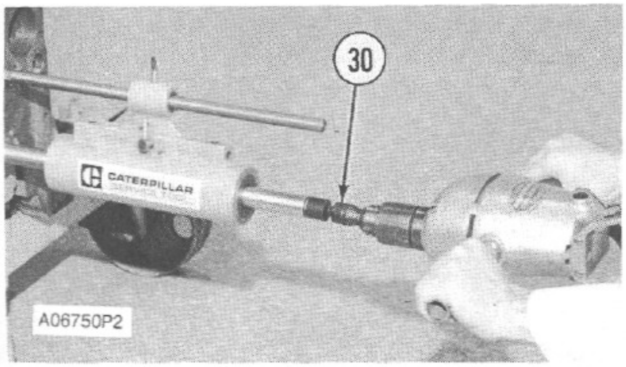


Later Feed Mechanism
(A) Lever.

Oil the bearing assemblies. Do not use lubricant on the cutter. Use one-half inch electric drill with universal joint (30) to feed the tool through the bores. Service main bearings with 0.25 mm (.010 in) oversize outside diameter are available to permit bores to be bored oversize. Bore block to 94.425 ± 0.013 mm (3.7175 ± .0005 in).

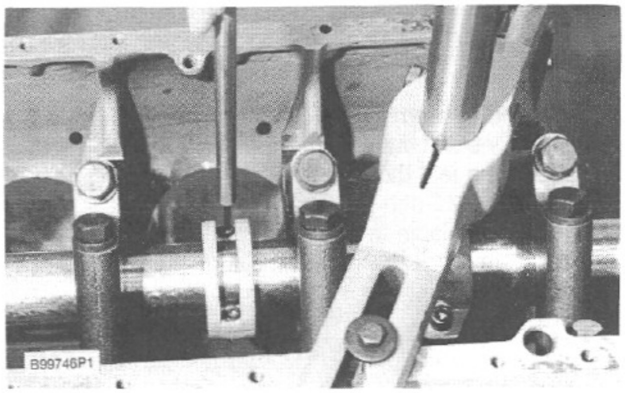


Boring Block
(30) 5P1630 Universal.



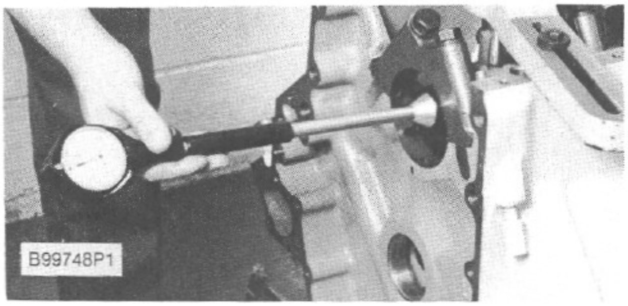
Driving Through Feed Mechanism
(Typical Example)
(30) 5P1630 Universal.

NOTE: If you use the later feed mechanism the tool can be driven from either the boring bar or the feed mechanism.



Positioning Tool Holder

When boring, if bearing assemblies interfere or tool does not reach next bore, reposition tool holder on boring bar.



Checking Bore

To check bores, set the 1P3535 Dial Bore Gauge to 94.425 mm (3.7175 in).

Cylinder Head and Valve Components

Check cylinder head for cracks before reconditioning.

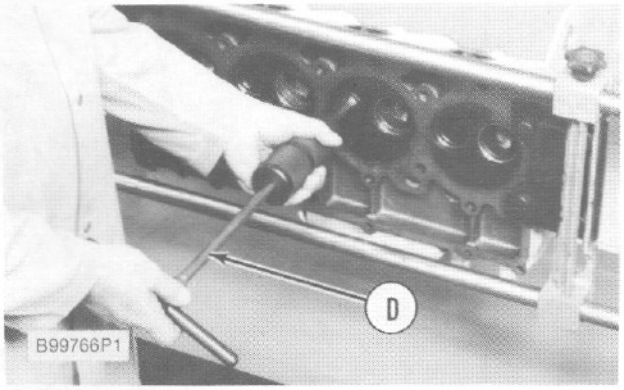
Flatness of the cylinder head should be within 0.15 mm (.006 in) total, and a maximum of 0.08 mm (.003 in) for any 152.4 mm (6.00 in) span. A maximum stock removal of 0.25 mm (.010 in) is permissible when resurfacing the head.

Always check the thickness of a cylinder head before resurfacing. The cylinder head may have been resurfaced before and would not have enough stock to be resurfaced again.

To check the thickness of a cylinder head, measure through the fuel injection nozzle holes at each end of the cylinder head. For the correct thickness of the cylinder head, see the topic Cylinder Head in the Specifications.

The valve seat insert for the exhaust valve can be replaced. The intake valve seat may be a replaceable seat insert or the seat may be machined into the cylinder head. When the seat for a non-replaceable intake valve has been machined to the limits, the cylinder head can be bored (machined) for a valve seat insert. See, Specification for dimensions given.

To remove the intake and exhaust valve seats that have replaceable inserts, use the 8S7170 Valve Seat Insert Puller Group.



Removing Exhaust Valve Seat Insert

Freeze the intake or exhaust valve seat inserts and use the 8S7170 Valve Seat Insert Puller Group to install inserts into head. Be sure bores are clean, free of burrs, and the insert has a good press fit into the bore.

After inserts are installed, grind the seat face of the insert to be sure it is flat, has the correct angle, and is in alignment with the bore in the valve guide.

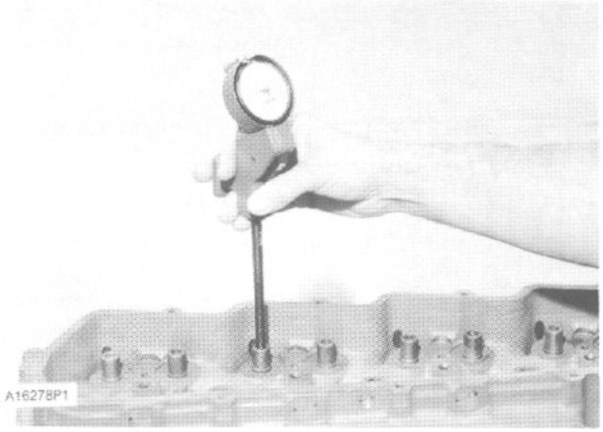
For specifications, see VALVE GRINDING SPECIFICATIONS CHART.

NOTE: Replace intake and exhaust valve seat inserts when valve seat width or valve head-to-cylinder head face cannot be machined to the correct specification. For specifications, see VALVE GRINDING SPECIFICATIONS CHART.

Clean valve guides of all carbon and oil, using the 5P7176 Brush and a solvent.

The valve guides are cast in the cylinder heads. Check each valve guide bore size 19.1 mm (.75 in) deep from each end. The bore size is 9.512 ± 0.013 mm (.3745 ± .0005 in) and the maximum size worn is 9.550 mm (.3760 in). Valve guides worn more than the maximum wear size, can be restored by original tolerances through knurling.

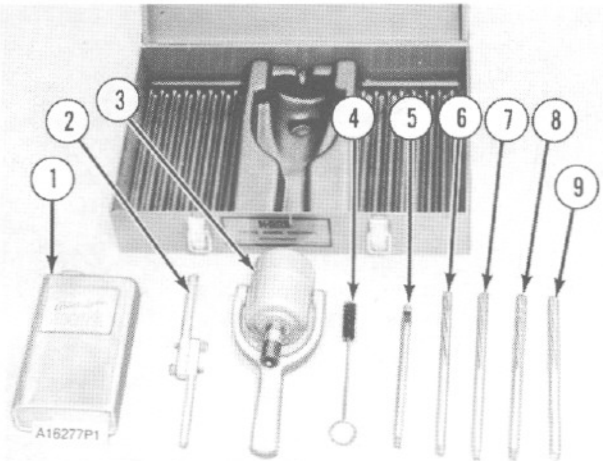
Use the 5P3536 Valve Guide Gauge Group to check the bore of the valve guides. Special Instruction, Form No. GMG02562 gives complete and detailed instructions for use of the 5P3536 Valve Guide Gauge Group.



Using 5P3536 Valve Guide Gauge Group

NOTE: If valve guide bore is larger than 9.68 mm (.381 in), knurling may not restore the guide to original tolerances.

The following procedure can be used to knurl valve guide bores using the 5P5170 Knurling Group:



5P5170 Knurling Group
(1) 5P5178 Lubricant. (2) 5P5187 Tap Wrench. (3) 5P5177 Speed Reducer (7 to 1). (4) 5P5176 Brush. (5) 5P5175 Knurling Arbor. (6) 5P5171 Reamer (.371 in). (7) 5P5172 Reamer (.372 in). (8) 5P5173 Reamer (.373 in). (9) 5P5174 Reamer (.374 in).

1. Clean and buff head, guides and valves. Check valve stem diameter. The intake valve stem diameter is 9.462 ± 0.013 mm (.3725 ± .0005 in) and the minimum size worn is 9.423 mm (.3710 in). The tapered stem exhaust valve has a stem diameter of 9.436 ± 0.013 mm (.3715 ± .0005 in) at the keeper end of the stem, and 9.411 ± 0.013 mm (.3705 ± .0005 in) at the head end of the stem. The minimum size worn is 9.373 mm (.3690 in).

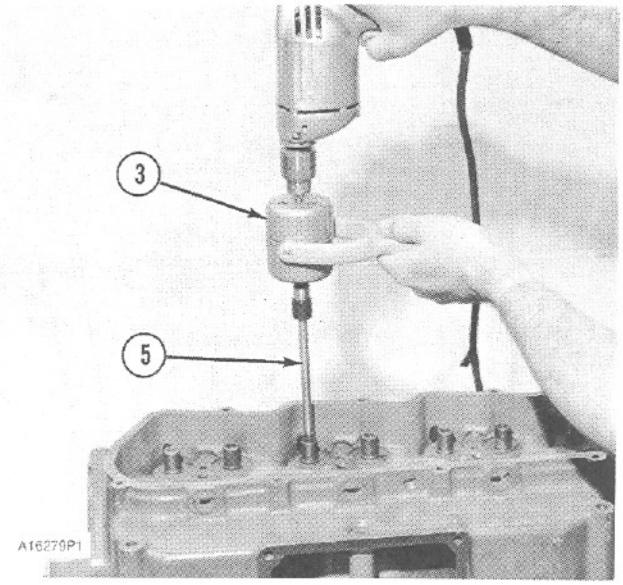
2. Place head on the FT806 Cylinder Head Bench or 8S6691 Cylinder Head Stand with rocker arm side toward you.

NOTE: Use FT967 Adapter Plates to mount head on FT806 Cylinder Head Bench.

3. Dip the 5P5176 Brush (4) into the 5P5178 Lubricant (1) and run the brush through the guide.

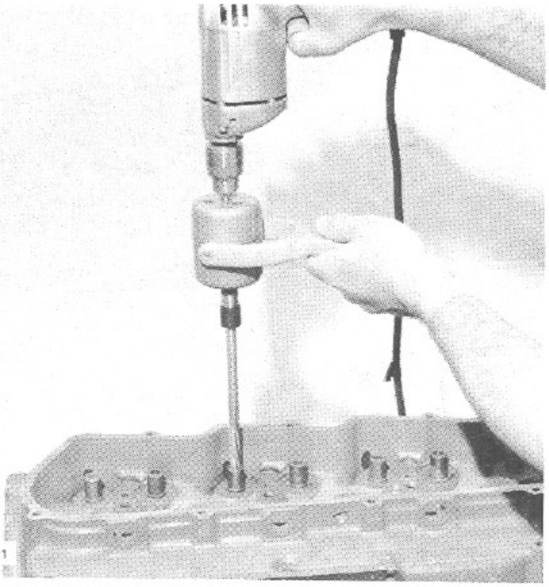
NOTE: The 5P5178 Lubricant is specially formulated for knurling cast iron guides and will prolong arbor life. If not available, use only Black Sulfur cutting oil or parafin base oil.

4. Dip the 5P5175 Knurling Arbor (5) into the 5P5178 Lubricant just prior to knurling. Use the 5P5177 Speed Reducer (3) and a ¼ inch electric drill (1200 to 1600 rpm recommended) to drive the arbor. Hold the speed reducer and drill firmly during knurling. Do not push or guide arbor during knurling.



Knurling Guide
(3) 5P5177 Speed Reducer. (5) 5P5175 Knurling Arbor.

5. Select the reamer that is closest to the size of the valve stem that is to be used and ream the guide using the speed reducer and ¼ inch electric drill. Push firmly to ream.



Reaming Guide

NOTE: It is not necessary to use lubricant for reaming.

6. Clean the valve guides with brush and solvent.

7. Install the valve. It is permissible to use a maximum force of 27 N (6 lb) with no oil to install the valve. Should valve not fit, use next size larger reamer and ream as in Step 5.

8. Thoroughly clean the valve guide bores after knurling.

The following procedure may be used to knurl valve guide bores using the United Tool Process:

1. Clean and buff head, guides and valves. Check valve stem diameter. The intake valve stem diameter is 9.462 ± 0.013 mm (.3725 ± .0005 in) and the minimum size worn is 9.423 mm (.3710 in). The tapered stem exhaust valve has a stem diameter of 9.436 ± 0.013 mm (.3715 ± .0005 in) at the keeper end of the stem, and 9.411 ± 0.013 mm (.3705 ± .0005 in) at the head end of the stem. The minimum size worn is 9.373 mm (.3690 in).

2. Place head on the FT806 Cylinder Head Bench or 8S6691 Cylinder Head Stand with spring end of valve guides toward you.

NOTE: Use FT967 Adapter Plates to mount head on FT806 Cylinder Head Bench.

3. Select the drill jig that corresponds in size to the valve guide. Use the ³⁄₁₆ in drill and stop in a slow speed drill. Drill an offset hole in guide 3.2 to 4.8 mm (⅛ to ³⁄₁₆ in) deep (hole to be drilled on exhaust manifold side of guide).

4. Using the proper size knurling tool and wheel, insert tool into guide and place wheel edge in offset notch. Place one drop of lubricant in each offset notch before knurling, and one drop on wheel after installing wheel in knurling tool. Use straight hex blade provided to match knurling tool and adapter in speed reducer. Hold outer shell of reducer from turning and start drill. Follow the rotating tool with slight pressure through the guide.

NOTICE

Use the mechanical speed reducer for all knurling and reaming as excessive speed and torque destroys tools. If possible, use a drill with a no load speed of 600 rpm.

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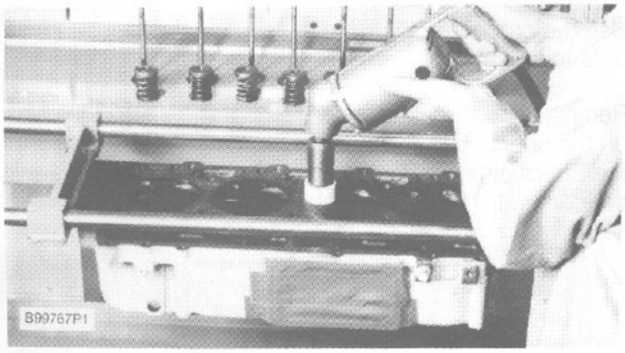
5. After knurling all guides, and before reaming, try valve in each end of guides. They should not fit into guides. If valves will go in either end of guides, the guides must be knurled again using the next size wheel. Ream the guides with a .374 in reamer before knurling. Repeat knurling and reaming process until valves will not fit into guides.
6. Ream valve guide bores to 9.512 ± 0.013 mm (.3745 ± .0005 in). To ream valve guide bore use a .374 in reamer. The reamer will ream the bore 0.013 to 0.020 mm (.0005 to .0008 in) over the size marked on the reamer.
7. After reaming, clean guides thoroughly before checking valve guide bore size.
8. Before installing valves, clean valve guide bores with the 1P5571 Brush and a strong detergent. Stroke each bore several times with the brush rotating to remove all dirt and loose chips.

After the valve guides are knurled, the valves and valve seats must be ground to provide proper sealing. For valve grinding specifications, see VALVE GRINDING SPECIFICATIONS CHART.



Grinding Valve Seats

VALVE GRINDING SPECIFICATIONS		
Seat Angle Valve Head Diameter	45 ½° ± ½° 45.82 ± 0.13 mm (1.804 ± (.005 in)	30 ½° ± ½° 53.19 ± 0.13 mm (2.094 ± .005 in)
Seat Width (Maximum)	2.67 mm (.105 in)	3.05 mm (.120 in)
Seat Outside Diameter (new)	44.07 ± 0.13 mm (1.735 ± .005 in)	52.23 ± 0.13 mm (2.045 ± .005 in)
Seat Outside Diameter (maximum)	44.70 mm (1.760 in)	52.45 mm (2.065 in)
Angle to Grind Insert to Reduce Seat Maximum Diameter	15°	15°
Valve Face Angle	45° ± ¼°	30° ± ¼°
Valve Lip Thickness (new)	1.60 mm (.063 in)	2.31 mm (.091 in)
Valve Lip Thickness (minimum)	1.27 mm (.050 in)	1.78 mm (.070 in)
Valve Head Diameter	45.82 ± 0.13 mm (1.804 ± (.005 in)	53.19 ± 0.13 mm (2.094 ± .005 in)
Maximum Distance Valve Head to Cylinder Head Face (Closed Valve)	2.16 mm (.085 in)	1.73 mm (.068 in)
Minimum Distance Valve Head to Cylinder Head Face Closed Valve)	1.27 mm (.050 in)	0.91 mm (.036 in)

Valve Springs

Check valve springs with the 8S2263 Valve Spring Tester. Springs not meeting Specifications should be replaced.

VALVE SPRING SPECIFICATIONS		
Item	9N5495 Spring	9N5496 Spring
Length-test force applied	42.47 mm (1.672 in)	45.47 mm (1.790 in)
Test force	91.2 ± 9.0 N (20.5 ± 2 lb)	185.0 ± 18.0 N (41.6 ± 4 lb)
Use again minimum load at length under test force	81.9 N (18.4 lb)	166 N (37.3 lb)
Length of spring at valve open position	27.23 mm (1.072 in)	30.23 mm (1.190 in)
Use again minimum load at valve open position	295 N (66.3 lb)	600 N (135 lb)
Free length after test	48.77 mm (1.920 in)	51.77 mm (2.038 in)
Outside diameter	26.67 mm (1.050 in)	39.62 mm (1.560 in)
Spring must not be bent more than	1.70 mm (.067 in)	1.80 mm (.071 in)

Connecting Rods

Piston Pin Bearing Removal And Installation

The 5P8639 Press Group and the 6V6100 Tool Group are used to remove and install the piston pin bearings in the connecting rods. Use the procedure that follows to remove and install the piston pin bearing from the connecting rod.

Remove the crankshaft bearing from the large end of the connecting rod and install the cap on the rod.

Put the connecting rod in an oven and get the temperature of the rod to 204°C (400°F).

Put the 6V4819 Spacer in the counterbore of the base plate. Be sure the spacer is in the bore straight and is against the bottom of the counterbore. Put the connecting rod, with the part number up, on the base plate so that the post assembly is in the center of the piston pin bearing.

Install the pin for the large end of the connecting rod in the center of the bearing bore. Put the 5P8653 Adapter over the post assembly and into the piston pin bearing. Make sure the alignment hole in the adapter is in line with the hole in the base plate. Install the 5P8641 Clamp Bar and the clamp pin on the large end of the connecting rod.

Put a new piston pin bearing on the 5P8653 Adapter. The bearing joint must be in alignment with the hole in the adapter. Put the 5P8645 Push Adapter, with the tapered side down, on the post assembly and on top of the 5P8653 Adapter. Make sure the alignment hole in the push adapter is in alignment with the bearing joint and the holes in the 5P8653 Adapter and the base plate.

Put the pusher on the 5P8645 Push Adapter and use the press to push the old bearing out and the new bearing in. Use the press until the push adapter makes full contact with the connecting rod. Remove the tools and the connecting rod from the press group.

NOTE: The piston pin bearing must be bored (machined to size) before the connecting rod can be used.

Check for Connecting Rod Distortion

The 5P2050 Connecting Rod Checking Fixture is used to check for bearing bore center-to-center distance and for piston pin bearing bore to crankshaft bearing bore alignment. The checking fixture can be used to check connecting rods with or without the piston pin bearing installed.

To check connecting rods that are to be reconditioned, the fixture must first be adjusted to the correct bearing bore center-to-center distance. Use a connecting rod of known length (master rod) for adjustment.

Remove the connecting rod bearing and install the cap on the connecting rod and tighten the nuts as shown in the SPECIFICATIONS. Remove the piston pin bearing from the connecting rod.

Put the 5P2041 Pin Mandrel in the piston pin end of the master rod. Install the 5P2013 Plunger Extension on the plunger of the 5P2053 Crank Mandrel. Install the 5P2051 Position Arm on the end of the crank mandrel. Put the crank mandrel in the crankshaft bearing bore of the master rod. Move the position arm so it is in alignment with the centerline of the pin mandrel. Turn the actuator knob on the end of the crank mandrel and tighten the mandrel in the rod.

Put the master connecting rod on the checking fixture. Move the dial indicator holder until both indicators show approximately 0.25 mm (.010 in) less than one complete revolution. Turn the dial face of each indicator until the hand is on zero.

Remove the connecting rod from the fixture; turn the rod 180° horizontally and put the rod on the fixture again. If the dial indicators read zero, the fixture is adjusted correctly. If there is a different reading on the dial indicators, move the dial face one-half the distance between zero and the reading. Remove the master rod from the fixture and remove mandrels from the master rod.

The checking fixture is now adjusted to check connecting rods for reconditioning.

Use the procedure that follows to inspect connecting rods to check if they are acceptable for reconditioning.

Remove the connecting rod bearing and install the cap on the connecting rod and tighten the nuts as shown in the Specifications. Remove the piston pin bearing from the connecting rod.

Put the 5P2041 Pin Mandrel in the piston pin bearing bore. Put the 5P2053 Crank Mandrel with 5P2013 Plunger Extension and 5P2051 Position Arm in the crankshaft bearing bore. Move the position arm in alignment with the centerline of the pin mandrel. Turn the actuator knob on the crank mandrel and tighten the mandrel in the rod.

Put the connecting rod on the checking fixture. Make a record of the readings on each of the dial indicators. Add the two readings and divide by two. The result is the average difference from the master connecting rod bearing bore center-to-center distance. The allowable difference for rods that are acceptable for reconditioning is ± 0.10 mm (± .004 in).

Leave the connecting rod in the checking fixture and check for both bores parallel. Make a record of the readings for both dial indicators. The total difference between indicator readings is the bores parallel dimension. The maximum allowable dimension is 0.15 mm (.006 in) for rods that are acceptable for reconditioning.

A check can also be made to check for connecting rod twist. Push one end of the pin mandrel against the locating surface behind it. Use a thickness gauge on the opposite end to check the clearance between the mandrel and the locating surface. Check both ends of the mandrel in this way for clearance. The amount of clearance is the twist in the rod. The maximum allowable twist is 0.30 mm (.012 in) for rods that are acceptable for reconditioning.

Boring Piston Pin Bearing

After new piston pin bearings are installed in the connecting rods, use the 5P3550 Connecting Rod Boring Machine to bore the piston pin bearings to the correct size.

Install the cap on the connecting rod (do not install the bearings). Tighten the nuts as shown in the Specifications.

Put the 5P2010 Mandrel on the spindle. Install nut and actuator, and tighten to hold mandrel in position. Install 5P2013 Plunger Extension on the plunger. The plunger must be in the up position within ± 3°. Loosen the spindle carrier, and use the handle on top to adjust the bearing bore center-to-center dimension. Move the carrier until the vernier scale reads 195.24 ± 0.03 mm (7.687 ± .001 in). This is the correct scale dimension to get a bearing bore center-to-center dimension of 200.66 ± 0.03 mm (7.900 ± .001 in). Tighten the carrier in this position.

Put the connecting rod in position on the mandrel, with the boss on the pin end of the rod towards the left. Turn the actuator until the connecting rod is tight on the mandrel.

Install 5P3552 Bushing in the front bracket. Push the locating arbor through the front bushing. Put 5P3541 Locating Bushing, with the large dimension of the diamond shape horizontal, on the locating arbor. Slide the locating arbor through the connecting rod and into the rear bushing. Slide the locating bushing into the rod. Push the locating rods until they are against the connecting rod, and tighten the rods firmly. Remove the locating arbor end bushing.

Fasten the 5P2023 Tool Bit Setting Gauge to the boring bar. Be sure the contact point of the indicator is against the boring bar. Adjust the indicator so the revolution counter and the hand are at zero. Move the tool bit setting gauge so that the contact point is against the cutting edge of the tool bit. Fasten the gauge in this position. Loosen the screw that holds the tool bit. Make an adjustment to the tool bit until the indicator reads 4.750 mm (.1881 in). Tighten the screw that holds the tool bit and recheck the setting.

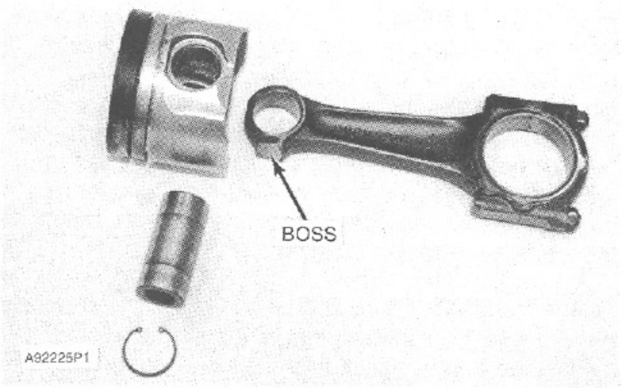
Put the boring bar through the connecting rod and into the rear bushing. Install the front bushing over the boring bar and into the bracket. Install 5P4777 Torsion Bracket on the rear of the boring machine. Put 5P4778 Feed Cylinder so the shaft goes through the rear bushing and into the boring bar. Tighten the setscrew in the boring bar to hold the feed cylinder shaft. Adjust torsion bracket and feed cylinder so the boring bar moves smoothly in rear bushing.

NOTE: Put the feed lever on the feed cylinder in the OPEN position before moving the boring bar.

With the feed lever in the OPEN position, move the boring bar until the tool bit is 3.2 mm (.13 in) from the bearing in the connecting rod. Put the feed lever in the CLOSED position and tighten the thumbscrew on the cylinder against the torsion bracket shaft. Install 5P2055 Flexible Adapter in the front of the boring bar and fasten an electric drill to the adapter. Put oil on the boring bar at the front and rear bushings. Start the drill and let the feed cylinder pull the boring bar through the bearing. Use a slow feed rate and do not push on the drill.

Check the bearing bore with a new piston pin. If the fit is too tight, do the boring operation again with the SAME tool bit setting.

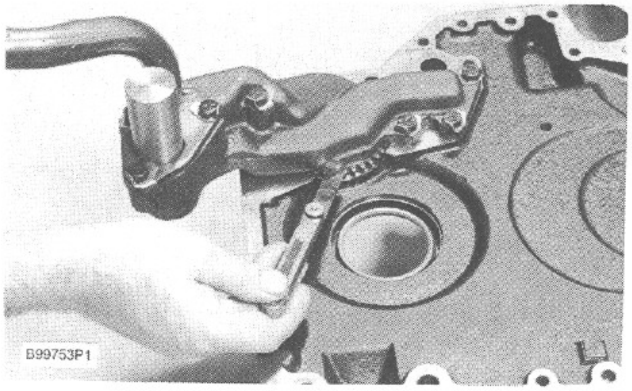
Install the connecting rod into the piston with the boss on the rod on the same side as the crater in the piston.



Connecting Rod And Piston

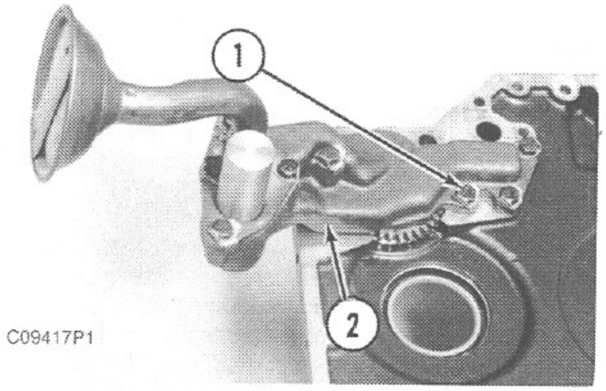
Oil Pump

Check oil pump end clearance. End clearance is 0.069 to 0.135 mm (.0027 to .0052 in) new.

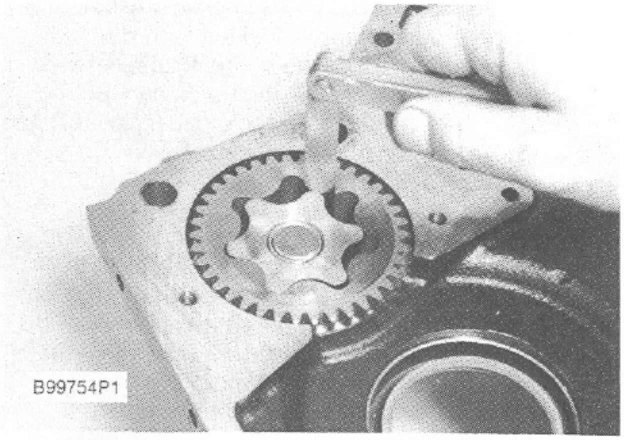


Checking End Clearance

Remove oil pump cover mounting bolts (1). Remove oil pump cover (2).



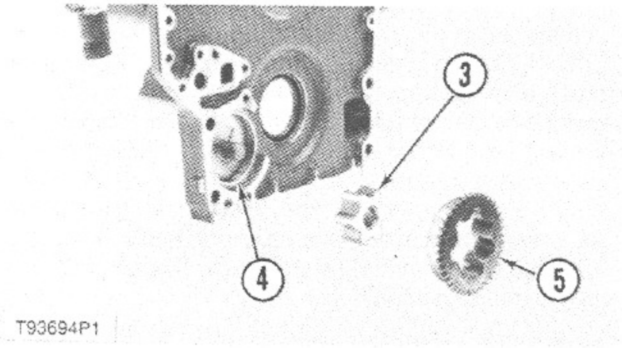
Oil Pump
(1) Bolts (four). (2) Oil pump cover.



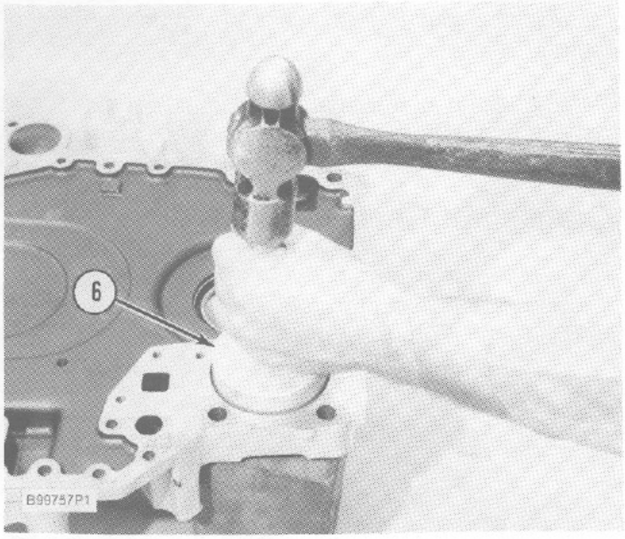
Checking Rotor Tip Clearance

Check oil pump rotor tip clearance. Rotor tip clearance is 0.05 to 0.20 mm (.002 to .008 in). Maximum rotor tip clearance is 0.28 mm (.011 in).

Remove outer rotor (5) and inner rotor (3). Check size of bearing (4). Size of bearing (4) is 71.224 ± 0.056 mm (2.8041 ± .0022 in). Replace bearing if necessary. Use an 8S2285 Driver (6) to install the bearing. For the correct location of bearing junction, see the topic Oil Pump in the Specifications.



Rotors Removed
(3) Inner rotor. (4) Bearing. (5) Outer rotor.



Installing Bearing
(6) 8S2285 Driver.

Clean all parts thoroughly before installing. Oil all component parts before installing. Install inner rotor (3), outer rotor (5), cover (2), mounting bolts (1) and locks. Tighten bolts to 24 ± 7 N•m (18 ± 5 lb ft) and secure with locks.

Crankshaft

Reconditioning of these crankshafts can be done by grinding the "journals" (bearing surface on the crankshaft for the connecting rod bearings and main bearings) 0.25 mm (.010 in), 0.51 mm (.020 in) or 1.27 mm (.050 in) "undersize" (smaller than the original size).

The diameter of the "journals" for the connecting rod bearings is 69.840 ± 0.015 mm (2.7496 ± .0006 in). The diameter of the "journals" for the main bearings is 88.887 ± 0.015 mm (3.4995 ± .0006 in). The minimum permissible diameter of the "journals" for the connecting rod is 69.814 mm (2.7486 in). The minimum permissible diameter for the "journals" for the main bearings is 88.862 mm (3.4985 in). Measure each "journal" in several places around the diameter to find the maximum wear point. If the diameter of any "journal" is smaller than the minimum permissible diameter, grind all of the "journals." Before a crankshaft is ground, check to be sure the crankshaft is not bent. To check for a crankshaft that is bent, place crankshaft main bearing journals 2 and 4 on 5P8637 V-Blocks. Use a dial indicator and check the runout (total indicator reading) for main bearing journals 1, 3 and 5.

The maximum total indicator reading is 0.13 mm (.005 in) for each journal. If the total indicator readings is more than 0.13 mm (.005 in) the crankshaft must be straightened before it is ground. Make reference to Guideline for Reusable Parts Procedure To Measure Bent Crankshafts, Form No. SEBF8030.

Another procedure must be used to determine if a bent crankshaft can be straightened.

Place the crankshaft main bearing journals 1 and 5 on 5P8637 V-Blocks. Use a dial indicator and check the runout (total indicator reading) of the center main bearing journal. If the total indicator reading is more than 1.27 mm (.050 in) the crankshaft cannot be straightened.

If the total indicator reading is less than 1.27 mm (.050 in), the crankshaft can be straightened. Before the crankshaft is straightened it must be heated to 177 to 232°C (350 to 450°F). Make reference to Guideline For Reusable Parts Procedure To Straighten Bent Crankshafts, Form No. SEBF8040.

With the crankshaft installed in the cylinder block, check the end play for the crankshaft. End play for the crankshaft is 0.08 to 0.25 mm (.003 to .010 in). Maximum permissible end play for the crankshaft is 0.36 mm (.014 in).

NOTE: If end play for the crankshaft is more than the maximum permissible end play, check the crankshaft thrust bearing.

Crankshaft Grinding Specifications

The dimensions and finish for grinding crankshafts are as follows:

Diameter (A) for connecting rod bearing journals is:

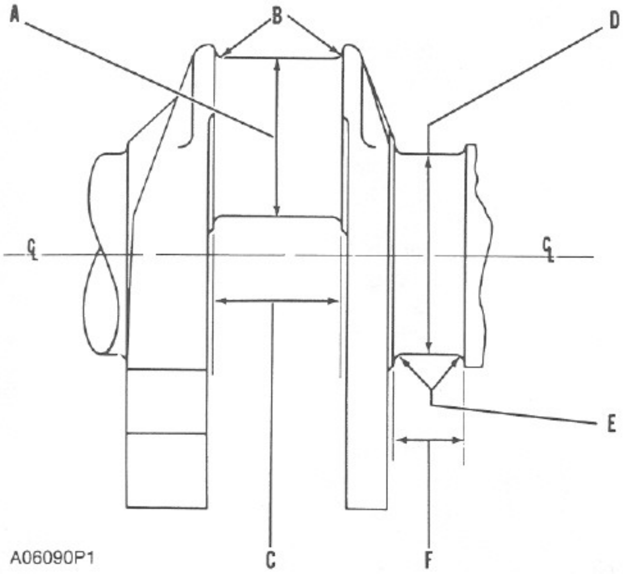
0.25 mm (.010 in) Undersize	69.586 ± 0.015 mm (2.7396 ± .0006 in)
0.51 mm (.020 in) Undersize	69.332 ± 0.015 mm (2.7296 ± .0006 in)
1.27 mm (.050 in) Undersize	68.570 ± 0.015 mm (2.6996 ± .0006 in)

Surface finish must be 0.25 micrometers (10 microinches) or less.

Radius (B) must be 2.54 ± 0.25 mm (.100 ± .010 in).

Surface finish must be 1.6 micrometers (63 microinches) or less.

The radius must blend smoothly with the newly machined journals.



Dimensions For Grinding
(A) Diameter of connecting rod bearing journals. (B) Radius on connecting rod bearing journals. (C) Width to grind journals for the connecting rods. (D) Diameter of main bearing journals. (E) Radius on main bearing journals. (F) Width to grind journals for the main bearings.

Width (C) is 58.77 ± 0.08 mm (2.314 ± .003 in)

Diameter (D) for main bearing journals is:

0.25 mm (.010 in) Undersize	88.633 ± 0.015 mm (3.4895 ± .0006 in)
0.51 mm (.020 in) Undersize	88.379 ± 0.015 mm (3.4795 ± .0006 in)
1.27 mm (.050 in) Undersize	87.617 ± 0.015 mm (3.4495 ± .0006 in)

Surface finish must be 0.25 micrometers (10 microinches) or less.

Radius (E) must be 2.41 ± 0.25 mm (.095 ± .010 in).

Surface finish must be 1.6 micrometers (63 microinches) or less.

The radius must blend smoothly with the newly machined journals.

Width (F) is 31.95 ± 0.05 mm (1.258 ± .002 in) for number 4 main bearing journal. Surface finish on the thrust faces of the number 4 main must be 0.45 micrometers (18 microinches) or less.

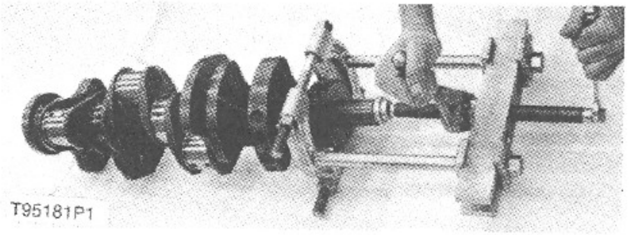
Width (F) is 32.21 + 0.51 − 0.25 mm (1.268 + .020 − .010 in) for number 2, 3 and 5 main bearing journals.

There is no width (F) for number 1 main bearing journal.

When grinding a crankshaft, no material can be removed from the crankshaft webs or counterweights.

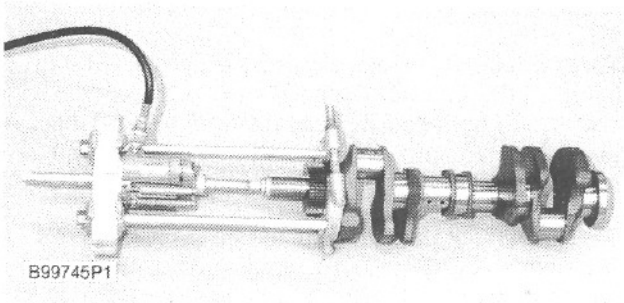
Crankshaft Gear Removal

Remove the gear using a 8B7548 Push Puller, 8B7551 Bearing Pulling Attachment, 8B7561 Step Plate, and 8H684 Ratchet Box Wrench.



Pulling Crankshaft Gear

The 1P0820 Hydraulic Puller Group can also be used to pull gear from crankshaft. Tools required are 1P0820 Hydraulic Puller Group, 8B7551 Bearing Pulling Attachment, 8B7549 Puller Legs (two), 8B7561 Step Plate, 3H0465 Plate (four), 1B4207 Nut (two) and 6V9061 Pump Group.



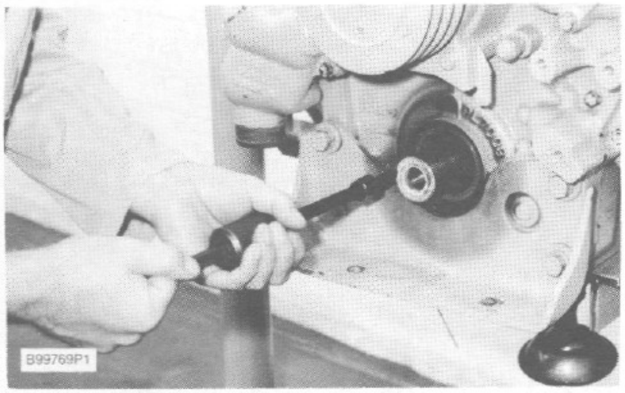
Using Hydraulic Puller

Crankshaft Gear Installation

1. Install the key in keyway of crankshaft. Remove all burrs from key and keyway inside of crankshaft gear.
2. Heat gear to 260°C (500°F) maximum.
3. Install gear on crankshaft with timing mark on gear facing front of crankshaft.

Crankshaft Front Oil Seal Removal

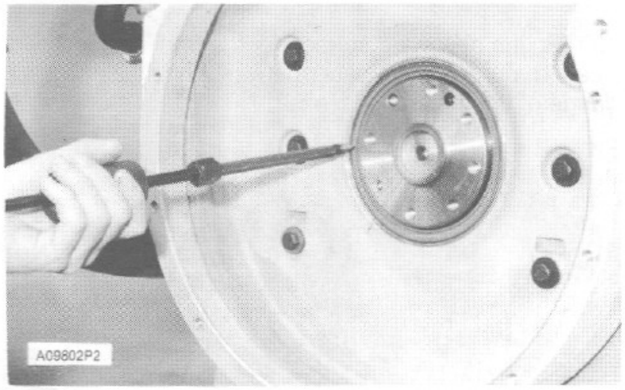
Remove the crankshaft from pulley. Use the 1P3075 Puller Group to remove the crankshaft front oil seal.



Removing Front Oil Seal
(Typical Example)

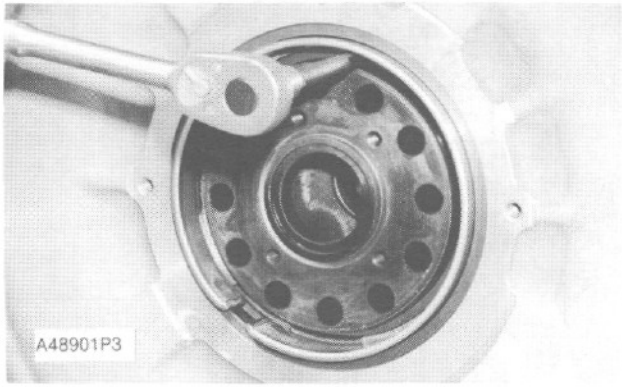
Remove Crankshaft Rear Seal and Wear Sleeve

Remove the crankshaft rear oil seal with the 1P3075 Puller Group.



Removing Rear Oil Seal

Install a 5P7338 Distorter Ring from the 5P7318 Wear Sleeve Distorter Group, in the rear seal bore. Install 5P7312 Distorter between distorter ring and wear sleeve. Turn the distorter until the edge of the tool makes a flat place (crease) in the wear sleeve. Do this in two or more places until the wear sleeve is loose. Remove the tools and wear sleeve.

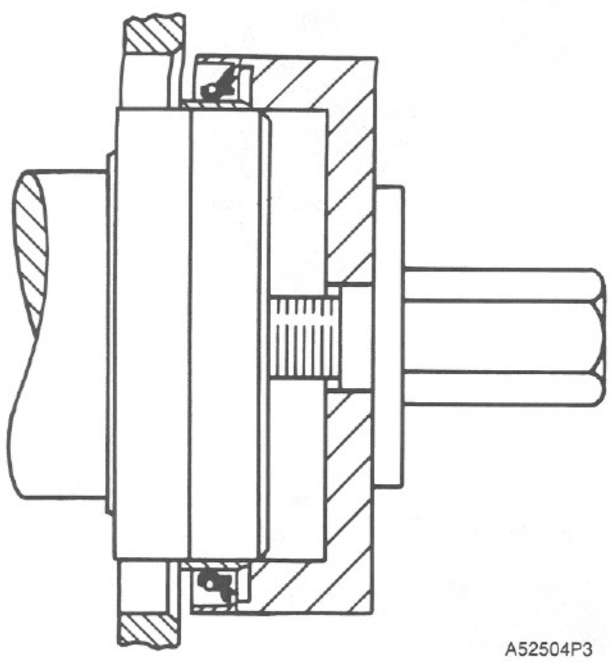


Removing Rear Wear Sleeve
(Typical Example)

Install Crankshaft Rear Seal and Wear Sleeve (Lip Type Seal)

The crankshaft rear seal and wear sleeve must be installed at the same time. Clean the wear sleeve inside diameter and the crankshaft outside diameter and put 6V1541 Quick Cure Primer on the surfaces. Put 9S3265 Retaining Compound on the outside diameter of the crankshaft and the inside diameter of the wear sleeve. Install 5P0290 Locator on the rear of the crankshaft. Put a sealer on the outer metal case of the seal.

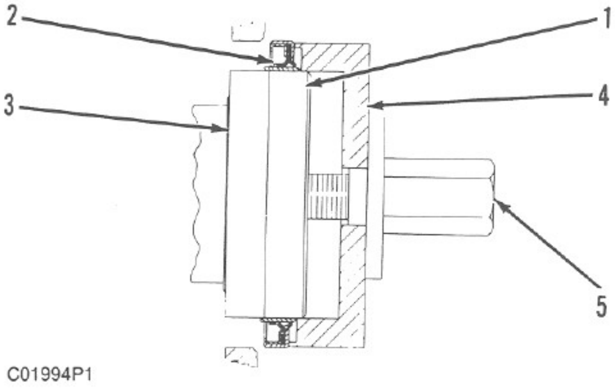
Put the wear sleeve and seal in position on the locater, with the outside diameter bevel on the wear sleeve away from the crankshaft. Be sure the lip of the seal is toward the engine. Put 5P7293 Installer in position on the locater. Put clean engine oil on the face of the nut and install it on the locater. Tighten the nut until the installer will not longer move.



Installing Crankshaft Rear Seal And Wear Sleeve

Install Crankshaft Rear Seal and Wear Sleeve (Hydrodynamic)

NOTE: New seal groups must be installed dry (no lubrication). Seal groups that have been separated must not be used. Only new seal groups are acceptable for installation.



Seal And Wear Sleeve Installation
(1) Locator. (2) Seal group. (3) Crankshaft. (4) Installer. (5) Nut.

1. Install the crankshaft rear seal and wear sleeve assembly with tooling as follows:

   a. Install locator (1) in position on the crankshaft.

   b. Use 6V1541 Quick Cure Primer to clean outer *diameter of the crankshaft flange and the inside* diameter of the wear sleeve.

   c. Put 9S3265 Retaining Compound on the outside diameter of the crankshaft and the inside diameter of the wear sleeve.

   d. Put seal group (2) on locator (1). Put installer (4) on locator (1). Put lubrication on the face of washer and nut (5). Install and tighten nut (5) until installer (4) comes in contact with locator.

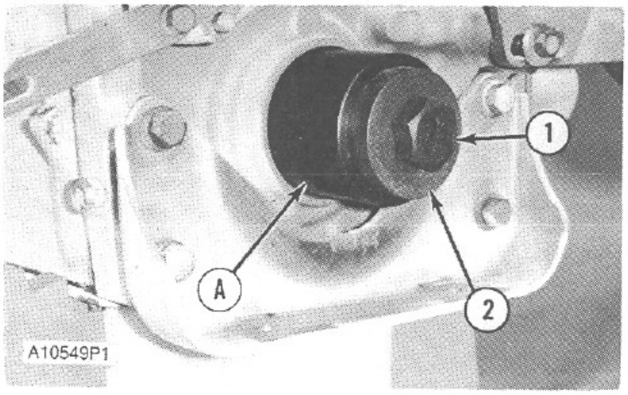
   e. Remove tooling, and check the wear sleeve and seal for correct installation.

Crankshaft Front Oil Seal Installation

1. Put the seal over the short end of the 5P4194 Installer Assembly (A). Put a sealer on the outer diameter of the seal metal shell. The lip of the seal must be toward the inside of the engine.

2. Put the seal and installer assembly (A) in position on the end of the crankshaft. Install bolt (1) and washer (2) that hold the crankshaft pulley in place. Tighten bolt (1) until the installer assembly (A) makes contact with the crankshaft gear.

NOTE: If a new wear surface for the front seal is needed, put 5P4230 Spacer between the seal and flange of the installer assembly.

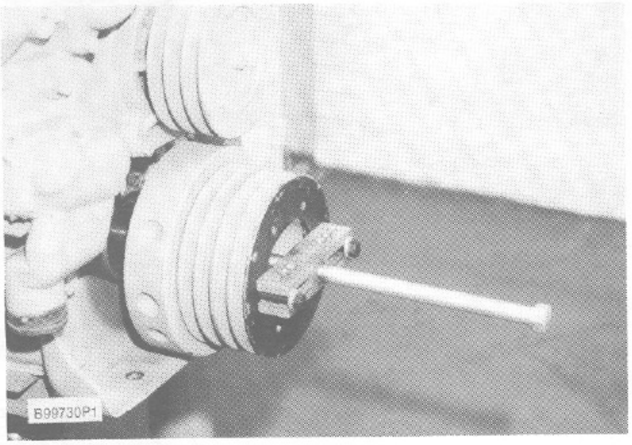


Installing Front Oil Seal
(1) Bolt. (2) Washer. (A) 5P4194 Installer Assembly.

3. Put engine oil on the lip of the seal before installing the pulley.

Crankshaft Pulley Removal

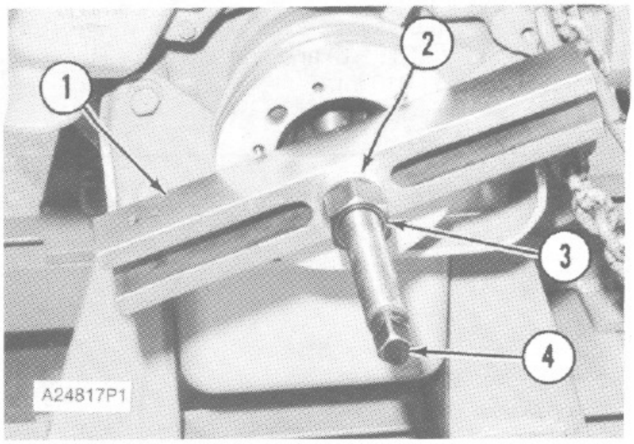
1. Remove pulley retaining bolt and washer.
2. Remove the pulley using a 5F7465 Puller Assembly, 8B7560 Step Plate, two 5M2894 Washer, and two 0S1571 Bolts.



Pulley Removal
(Typical Example)

Crankshaft Pulley Installation

1. Lubricate lip of crankshaft front oil seal and the sealing surface of crankshaft pulley with engine oil (SAE 30).
2. To install pulley, start pulley on crankshaft. Put screw (4) from the 8B7548 Push Puller into the crankshaft until it bottoms out. Put cross bar (1) from the 8B7548 Push Puller onto screw (4). Install washer (2) and nut (3) onto screw (4). Hold screw (4) and turn nut (3) to press pulley onto crankshaft. When installed, the pulley hub will contact the crankshaft gear.
3. Remove the tool setup. Install the pulley retaining bolt and washer. Tighten the pulley retaining bolt to the torque shown in the specifications.



Installing Pulley
(1) Crossbar. (2) Washer. (3) Nut. (4) Screw.

Camshaft

Inspect the camshaft for wear or damage. There must be no pits or scuffing on the surface of the camshaft lobes. If damage is found on a camshaft lobe, inspect the valve lifter for that lobe for damage. Check the diameter of the camshaft bearing journals and the camshaft lobe height.

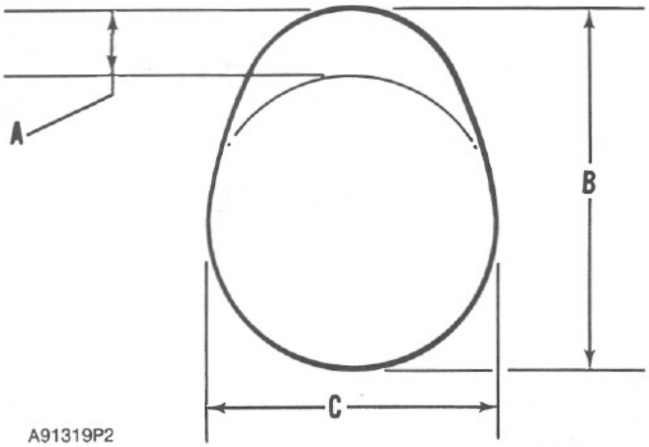
Camshaft bearing journals have a diameter of 63.500 ± 0.013 mm (2.5000 ± .0005 in) and the minimum diameter worn is 63.424 mm (2.4970 in).

To find lobe lift (A) of camshaft, use the following procedure:

1. Measure lobe height (B) of one exhaust and one intake lobe.
2. Measure base circle (C) of one exhaust and one intake lobe.
3. Subtract base circle (C) dimension (STEP 2) from lobe height (B) dimension (STEP 1). The difference is actual lobe lift (A).
4. The specified (new) lobe lift (A) is:

Camshaft used with roller lifters.	
(a) Exhaust lobe	9.40 mm (.370 in)
(b) Intake lobe	9.33 mm (.367 in)
Camshaft used with flat face lifters.	
(c) Exhaust lobe	9.40 mm (.370 in)
(d) Intake lobe	9.06 mm (.357 in)

5. The maximum permissible difference between actual lobe lift (STEP 3) and specified lobe lift (STEP 4) is 0.25 mm (.010 in).



Camshaft Lobe
(a) Lobe lift. (b) Lobe height. (c) Base circle.

With camshaft installed in the cylinder block, check end play. End play with new components should be 0.18 ± 0.08 mm (.007 ± .003 in). The maximum permissible end play is 0.51 mm (.020 in).

Valve Lifters

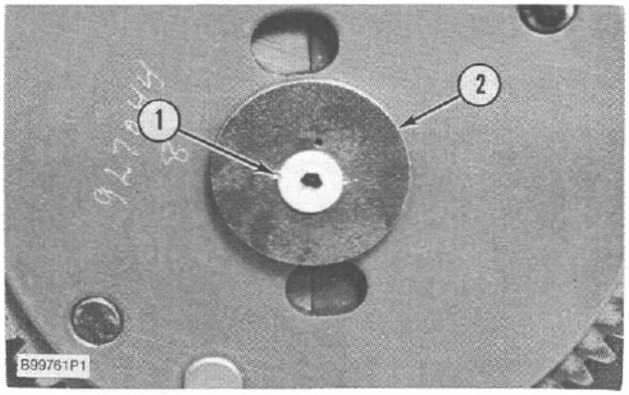
Inspect lifters for wear or damage. The roller must turn freely in the lifter. There must be no deep scratches (grooves) on the side of the lifter body, and there can be no pits or scuffing on the wear surface of the roller.

If the lifters do not have wear or damage, the lifter can be used again with a used camshaft.

NOTE: New lifter guide springs must be installed anytime the lifters are removed from the lifter bores.

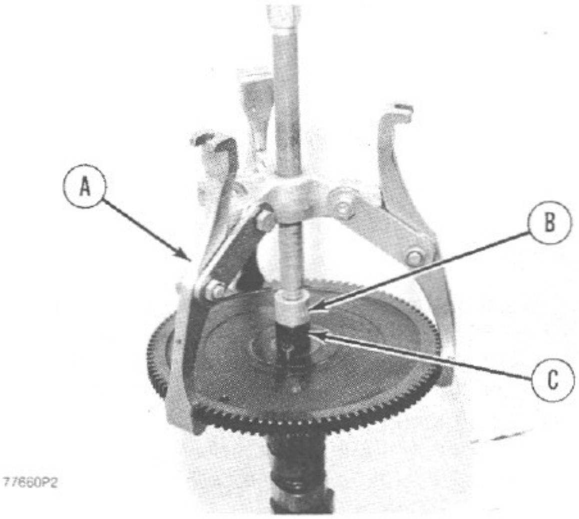
Camshaft Gears

1. Remove screw (1) and washer (2) from end of camshaft.



Removing Timing Advance Retaining Screw
(1) Screw. (2) Washer.

2. Remove timing advance unit from the camshaft.
3. Install puller (A), with spacer (C) over the shaft in the camshaft. Put spacer (B) on spacer (C) as shown and remove the gear from the camshaft.



Removing Gear
(Typical Example)
(A) 1P2321 Puller. (B) 8S5579 Spacer. (C) 9S9155 Spacer.

To install the gear use the following procedure:

1. Heat the gear to a temperature of approximately 204°C (400°F) before installing on the camshaft.

NOTICE
Do not heat the gear with a torch. Do not heat the gear to a temperature of more than 315°C (600°F). Heating the gear with a torch or to a temperature of more than 315°C (600°F) may cause the two drive dowels for the automatic timing advance to loosen and come out of the gear.

2. Align slot in gear hub with the pin in the camshaft. Install the gear on the camshaft with timing mark on gear aligned with timing mark on crankshaft gear. Be sure the gear is completely seated against the shoulder of the camshaft.

NOTICE

Do not drive the gear on the camshaft.

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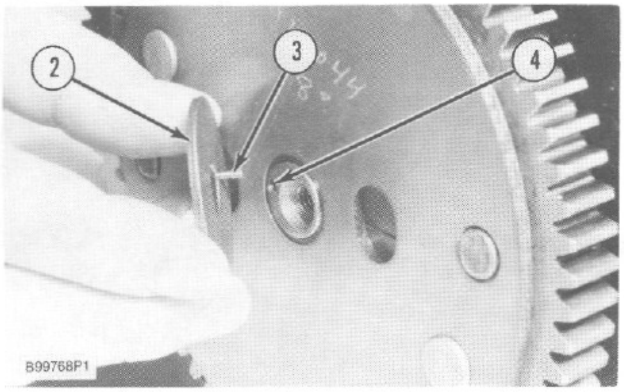
3. Align holes in weights with dowels in gear and install the automatic timing advance.
4. Align pin (3) in washer with hole (4) in camshaft and install washer (2).
5. Install screw (1) and tighten to 7.9 ± 0.6 N•m (70 ± 5 lb in). Stake screw in two places.



Installing Washer
(2) Washer. (3) Pin. (4) Hole.

NOTICE

Stake screw (1) carefully. Heavy blows on washer or screw can force the shaft extension too far into the camshaft and eliminate all end clearance.

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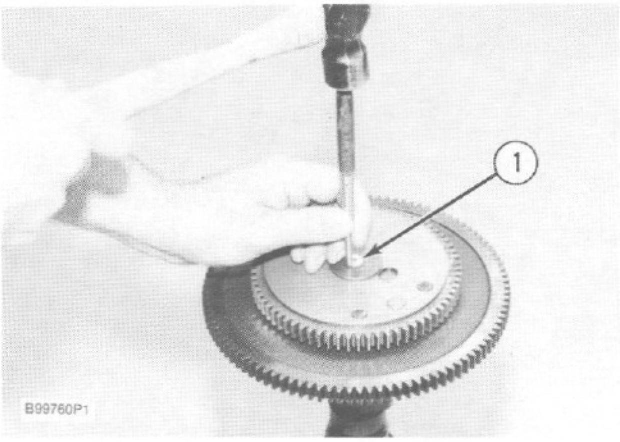
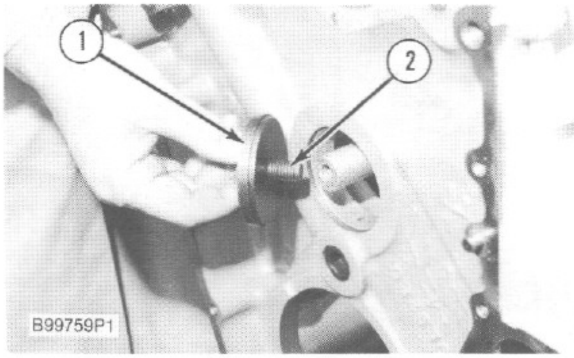
6. After screw (1) is staked, the gear and weight assembly requires 0.08 to 0.94 mm (.003 to .037 in) end clearance to prevent binding against the washer, camshaft end or camshaft gear.



Staking Screw
(1) Screw.

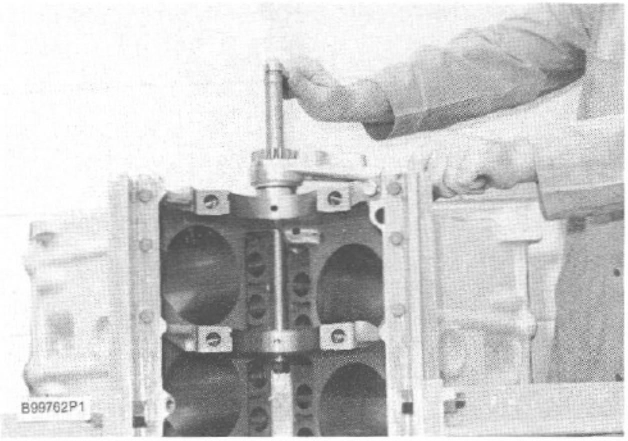
Camshaft Bearings Removal and Installation

Remove camshaft bearings using the 1P5544 Washer (1) and 0S0509 Bolts (2), from the 1P5545 Adapter Group, in conjunction with the 8S2241 Camshaft Bearing Removal and Installation Group, and the 8H0684 Ratchet Box Wrench.



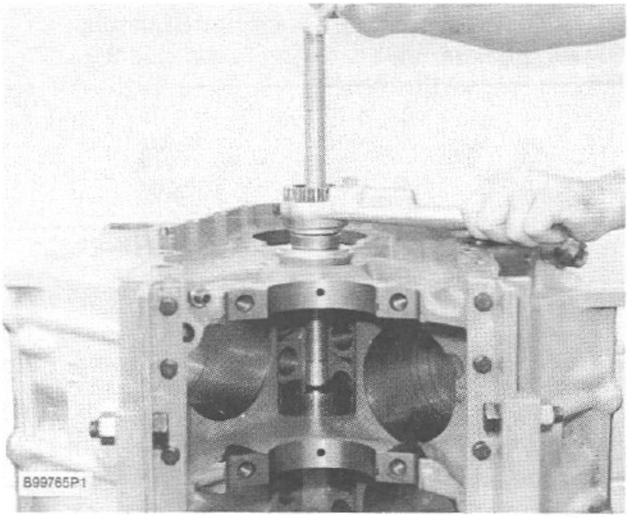
Installing Washer
(1) 1P5544 Washer. (2) 0S0509 Bolt.

With removal tools installed on cylinder block, remove bearings.



Removing Camshaft Bearings

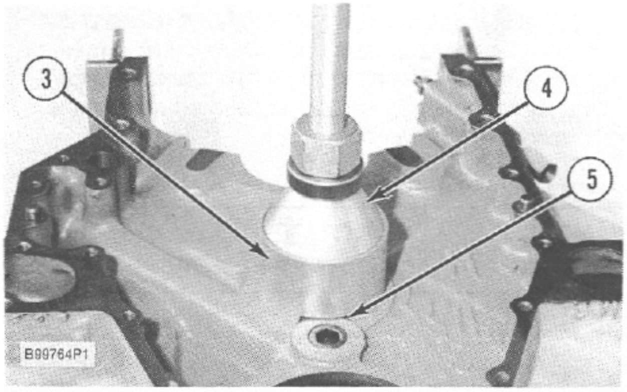
Use the 1P5545 Adapter Group in conjunction with the 8S2241 Camshaft Bearing Removal and Installation Group, and the 8S0684 Ratchet Box Wrench to install camshaft bearing.



Installing Camshaft Bearings

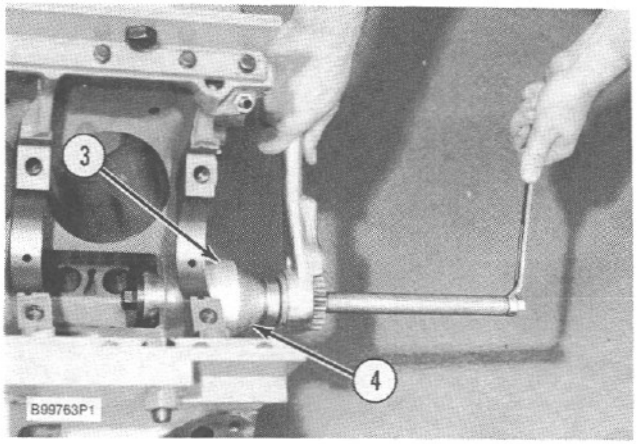
The 1P5545 Adapter Group pilots in the camshaft bearing bore and also pilots the bearing into the bore. This insures bearing alignment. Install bearings from chamfered side of the bore and align oil hole in bearings with oil holes in cylinder block.

To install the camshaft front bearing, it is necessary to machine a notch in the 8S8289 Tube (3) for clearance of the boss that projects above the camshaft bearing bore. Machine the notch 38.1 mm (1.50 in) wide, 9.5 mm (.37 in) deep, with a 3.2 mm (.13 in) radius or chamfer in the corners and on the edges.



Notch In Tube
(3) 8S8289 Tube. (4) 8S8288 Cone. (5) Notch.

Invert the 8S8288 Cone (4) and install it in the 8S8289 Tube (3) for installation of the camshaft front bearing.



Installing Camshaft Front Bearing
(3) 8S8289 Tube. (4) 8S8288 Cone.

Engine Test Procedure

Lubrication for a Rebuilt Engine

It is very important for a rebuilt engine to have "adequate" (needed) lubrication during the first seconds of operation. A "dry start" (without needed lubrication) on a rebuilt engine can cause bearing damage.

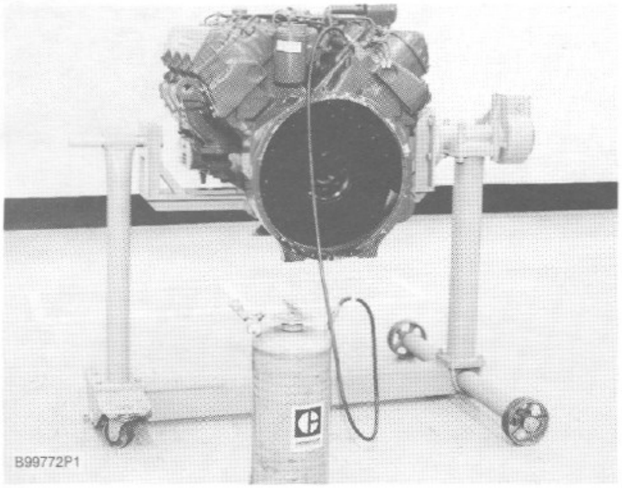
When an engine is rebuilt with new parts, oil is put on each part as it is installed. This is generally enough lubrication for engine start-up. However, this lubrication may not be enough or may be lost if the rebuilt engine is placed in storage for any length of time.

When a factory assembled short block assembly is installed, the oil used at the factory has to give this needed lubrication. However, the factory oil application can flow off the parts in a short block during storage or shipment. As a result the parts in a rebuilt engine will not have "adequate" lubrication at startup.

To prevent the possibility of a "dry start" and bearing damage during the first seconds of running, use the 1P0540 Flow Checking Tool Group, and shop air pressure to pressure lubricate (fill the main oil passage with oil under pressure) all rebuilt engines.

Procedure for Pressure Lubrication

1. Clean the tank of the 1P0540 Flow Checking Tool Group thoroughly.
2. Put approximately one gallon of engine oil in the tank.
3. Connect the tools to the engine as shown. The tap shown is connected to the main oil passage.



Pressure Lubrication
(Using the 1P0540 Flow Checking Tool Group)
(Typical Example)

⚠ WARNING

If shop air is used, set the tank regulator to the minimum kPa (psi) setting. If air pressure is too high, fittings and hoses can be blown off or the tank can explode causing personal injury. Do not exceed 415 kPa (60 psi) air pressure in the tank.

4. Add air pressure to the tank. Set the regulator at 240 ± 35 kPa (35 ± 5 psi). Although the tank does have a hand pump, it is difficult to get enough air pressure to do the job with the hand pump. Therefore, use of the shop air is recommended.
5. Let the one gallon of engine oil flow into the oil passage under pressure.

When filling the crankcase, put in one gallon of oil less than the recommendation in the Operation And Maintenance Guide, if engine has received this pressure lubrication application. Also if the engine is not going to be used for a long time, do the above procedure again before the first starting.

If shop air is not available for charging the tank, the hand pump may be used to get the minimum required pressure.

NOTICE

Do not use the same 1P0540 Flow Checking Tool Group for both "pressure lubrication application" and for checking fuel flow. Incorrect cleaning is probable if the tool is used for both fuel and lube oil. Even a minute amount of dirt in the fuel system can cause nozzle failure.

Initial Operation After Engine Reconditioning

The quality of oil control components used in Caterpillar engines is such that, following engine reconditioning (with Caterpillar Service Parts), only an initial operational check is necessary before continued operation in normal service.

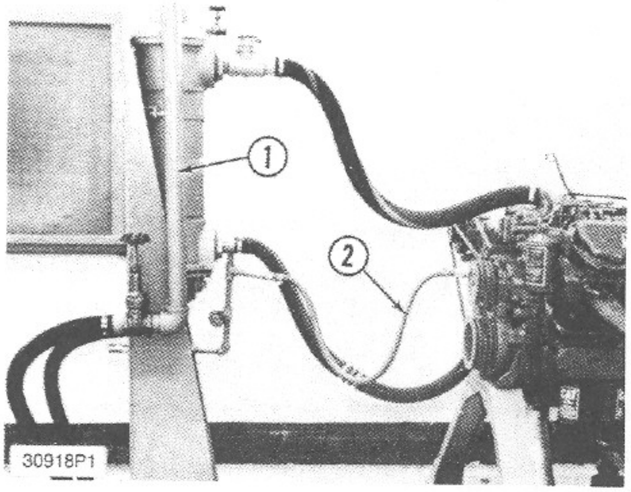
The purpose of this initial operation check is to: insure that the engine has been assembled properly; determine if proper pressures and temperatures are maintained in the lubrication, cooling and fuel systems; correct any leaks; perform necessary adjustments (such as valve clearance, governor high and low idle speeds, etc.); check the power setting of the engine.

To provide a safe, uniform initial operational check, the following procedure is recommended:

1. Motor engine at cranking speed until oil pressure is observed.
2. Operate engine for 10 minutes at low idle.
3. Operate engine for 15 minutes at half-load and ¾ rated speed.
4. Operate engine for 30 minutes at rated load and speed.

Dynamometer Test Precaution

To avoid possible engine damage while testing on a dynamometer, the thermostats must be installed and the shunt line connected as shown.



Shunt Line Connected To Engine
(Typical Example)